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Special theme:

eXtended Reality

Also in this issue's Research and Innovation section:

Advanced Integrated Evaluation of Railway Systems

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Beyond Compliance 2023: Forum on Digital Ethics in Research

by Anaëlle Martin (CCNE)

On 18-20 October 2023, the ERCIM Ethics Working Group co-organised with the CNPEN, the French National Committee for Digital Ethics, and the University of Porto, the second edition of the forum dedicated to digital ethics beyond compliance [L1] The hybrid event, which was held at the Faculty of Engineering of Porto, consisted of one tutorial, two keynotes and six topics and discussion sessions. The forum organisers have endeavoured to combine both theoretical and practical aspects of digital ethics in research, bearing in mind that in the context of the European AI Act and the war in Ukraine, researchers need to be pragmatic and open-minded. The program also left plenty of room for discussion, debate and dispute among participants, particularly in the session devoted to Environmental research ethics.

The first keynote was devoted to the fascinating and somewhat speculative topic of artificial consciousness, addressed from an epistemological perspective: the question was whether a 'digital mind' could be possible or even foreseeable in the future. It was also an opportunity to address the moral and philosophical question — often perceived as science fiction — of technological singularity, and to recall that the emergence of truly intelligent systems calls for an appropriate legal regime related to rights and responsibilities of digital persons. The closeness between digital ethics and artificial intelligence (AI) regulation was illustrated by the session that immediately followed, entitled 'AI: From ethics to regulation', in which relationship between AI ethics narratives, standardisation, certification, self-regulation and governance was masterfully highlighted. One of the speakers pointed out that, in absence of artificial general intelligence, there was a risk that algorithmic fairness would turn into a tool of distraction to avoid legal regulation [L2]. It would seem that in Europe this is not the case since European Union (EU) is at the cutting edge of AI regulation, after years of ethics guidelines and self-regulation. But despite its 'risk-based approach', the AI Act appears to leave gaps in the protection of individuals, as has been stressed in that session. The second session of the first day focused on the importance of science in a digital world. The speeches on this theme were particularly original, as shown by the example of the Citizen science, which is increasingly recognised as advancing scientific research and social innovation by involving general public in gathering and analysing empirical data. The issue of trustworthy digital data research was tackled from the perspective of ethnography, which emphasises, in its analytical tools and research practices, relations of awareness and power [L3].

The first session of the forum's second day began with presentations about data protection in the age of AI. Big data poses a new challenge for privacy when machine-learning techniques are used to make predictions about individuals. The need to deploy data privacy technologies has been raised several times, as well as the urge to move from theoretical work to practice in order to have positive impact on society [L4]. More specifically, in the big data context, the problematic status of inferred data in EU data protection law needs to be clarified. In order to remedy the accountability gap posed by big data analytics and artificial intelligence, some researchers call for a new data protection right: the "right to reasonable inference" which would be based on a rigorous justification. Another data protection concern involves machine-learning models, in context of secondary use of trained model. These models are a blind spot in data protection regimes; that is why they should be target of regulation before their application to concrete case. After a tutorial on research ethics in digital science, which recalled the importance of ethical and deontological reflection for (young) researchers [L5], discussions focused on the responsible use of generative AI in academia [L6], which is a highly topical issue today: 2023 was undoubtedly the year of generative AI and of ChatGPT in particular. The chatbot's performance drew public attention to Large Language Models (LLMs). Yet, while advances in AI have a potential in reshaping scientific tasks, many disciplines are addressing a "reproducibility crisis" due to questionable research practices and lack of transparency [L7]. For this reason, it is crucial to engage in exploratory work on LLMs use cases in science and to ensure that generative AI does not hinder trust in scholarly knowledge. Above all, researchers need to adopt a sober approach and an 'epistemic humility' to understanding the limitation of this technology, in the hype-laden climate surrounding OpenAI. The final session of the second day focused on the environmental research ethics. This provided the opportunity for a radical doctrinal proposal formulated succinctly: in order to ensure the resilience of ecosystems and sustainability of life on Earth, we need to dismantle the deadly illusions of AI and to restore our animal and social intelligence to its rightful place. The other speakers on the panel were more moderate, focusing mainly on AI models' carbon footprint in different stages of their life cycle and researchers' moral obligation to consider the environmental impacts associated with their research [L8].

The third and final day of the forum focused on ethical guidance and review for research beyond human subjects. From a methodological point of view, specific and even sectorial ethics guidelines are needed in the European ethics evaluation scheme. The principle of transparency, for example, must be applied and adapted to the fields in which AI is widely used, such as healthcare or virtual reality. The arrival of new digital entities such as metaverse avatars and healthcare chatbots reinforces the importance of ethical principles like the 'principle of maintaining distinctions' (between human beings and digital entities), which could possibly be achieved through watermarks [L9]. It is also imperative to take regulatory decisions to impose that principle in order to address legal issues of liability and sanctions. The session further shed light on the importance of distinct ethics conceptual approach for projects funded in the area of AI technologies, in order to enable human-centric and robust digital research ecosystem. More generally, the need for education, training and expertise was strongly emphasized for research ethics in digital sciences. Finally, the question of operationalisation of safety principles in AI research within the context of open source practices was discussed: safety, accountability, fairness, explainability, and data stewardship are required to ensure trustworthy AI development. The final keynote was dedicated to the "Vienna manifesto on Digital Humanism" which is based on the premise that digitalisation presents many opportunities but also raises serious concerns: monopolisation of the Web, rise of extremist opinions, loss of privacy, spread of digital surveillance, etc. The Vienna manifesto encourages academic communities, policy makers and industrial leaders to participate in policy formation. It is a call to act on current technological development in order to shape technologies in accordance with human values, instead of allowing technologies to shape humans. This sensible roadmap brought the 2023 edition of the forum on digital ethics in research to a close.

The programme of the Forum including several links to the presentations is available at [L1]

Links:
[L1] https://www.ercim.eu/beyond-compliance
[L2] https://kwz.me/hDi
[L3] https://www.youtube.com/watch?v=7PTTfQlEKvg
[L4] https://www.youtube.com/watch?v=tRjdf-WQyds
[L5] https://www.youtube.com/watch?v=zk7yk_ruzOI
[L6] https://www.youtube.com/watch?v=rR0biPkX3-w
[L7] https://kwz.me/hDh
[L8] https://www.youtube.com/watch?v=aL_2qV9b0Gk; https://kwz.me/hDs
[L9] https://www.youtube.com/watch?v=kGG1bOHxPMA; https://kwz.me/hDa

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Call for Contributions

Forum Beyond Compliance 2024: Research Ethics in the Digital Age

Budapest, 14-15 October 2024

Submission deadline: 10 June 2024.
Notification of acceptance: July 10th, 2024.
Accepted contributions should be presented on-site.

For the third edition of the Forum, co-organized by ERCIM, SZTAKI, and the CCNE-numérique, the program will consist of invited presentations, invited contributions to round tables, a tutorial session, and selected contributions based on the answers to this call. The program will be structured into six topical sessions focusing on ethical issues in digital research about Cultural Influences, Democracy, Regulation Making, Cooperative Agents, Digital Health, and Emerging Topics; and two sessions for a Tutorial and Selected Contributions. We invite the community to propose contributions in the form of short presentations. These can include case study reports, novel developments from research projects, policy recommendations, or proposals and hypotheses put forward for discussion.

Proposals are solicited as extended abstracts not exceeding two pages, in English, written using the Helvetica Neue 11pt font. These will undergo a lightweight review process by the workshop organizing committee, being evaluated for topical fit, and - depending on the type of submission - novelty of contribution, or perspective offered, or potential impact of contribution, or controversiality and potential for discussion. The selected contributions, possibly extended from the selected abstracts, will be published on the forum's web page.

Submissions should be made by emailing the extended abstract to beyond-compliance-2024@ercim.eu.

The organizing committee of the Beyond Compliance Forum is the Digital Ethics Task Group of ERCIM, currently composed of:
- Christos Alexakos (ISI/ATHENA RC, Greece)
- Emma Beauxis-Aussalet (VU, Netherlands)
- Gabriel David (INESC TEC, Portugal)
- Claude Kirchner (CCNE and Inria, France)
- Guenter Koch (AARIT, Austria, and Humboldt Cosmos Multiversity, Spain)
- Sylvain Petitjean (Inria, France)
- Andreas Rauber (TU Wien, Austria)
- Vera Sarkol (CWI, Netherlands)

More information:
https://www.ercim.eu/beyond-compliance

ERCIM “Alain Bensoussan” Fellowship Programme

The ERCIM postdoctoral Fellowship Programme has been established as one of the premier activities of ERCIM. The programme is open to young researchers from all over the world. It focuses on a broad range of fields in Computer Science and Mathematics.

The fellowship scheme also helps young scientists to improve their knowledge of European research structures and networks and to gain more insight into the working conditions of leading European research institutions. The fellowships are of 12 months duration (with a possible extension), spent in one of the ERCIM member institutes.

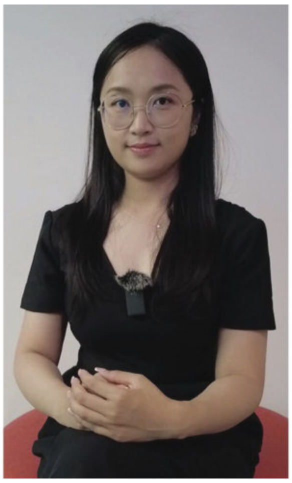
Where are the fellows hosted?

Only ERCIM members can host fellows. When an ERCIM member is a consortium the hosting institute might be any of the consortium’s members. When an ERCIM Member is a funding organisation, the hosting institute might be any of their affiliates. Fellowships are proposed according to the needs of the member institutes and the available funding.

The fellows are appointed either by a stipend (an agreement for a research training programme) or a working contract. The type of contract and the monthly allowance/salary depends on the hosting institute.

ERCIM encourages both researchers from academic institutions and scientists working in industry to apply.

> “The ERCIM fellowship has been an incredible journey of growth and discovery for me. This has not only broadened my academic perspective but also provided me with invaluable networking opportunities and insights that would shape my future career.
>
> **Feiran ZHANG**
> Former ERCIM Fellow



Why to apply for an ERCIM Fellowship?

The Fellowship Programme enables bright young scientists from all over the world to work on a challenging problem as fellows of leading European research centers. In addition, an ERCIM fellowship helps widen and intensify the network of personal relations and understanding among scientists. The programme offers the opportunity to ERCIM fellows:

- to work with internationally recognized experts,
- to improve their knowledge about European research structures and networks,
- to become familiarized with working conditions in leading European research centres,
- to promote cross-fertilization and cooperation, through the fellowships, between research groups working in similar areas in different laboratories.

Equal Opportunities

ERCIM is committed to ensuring equal opportunities and promoting diversity. People seeking fellowship within the ERCIM consortium are not discriminated against because race, color, religion, gender, national origin, age, marital status or disability.

Conditions

Candidates must:

- have obtained a PhD degree during the last eight years (prior to the application year deadline) or be in the last year of the thesis work with an outstanding academic record. Before starting the grant, a proof of the PhD degree will be requested;
- be fluent in English.

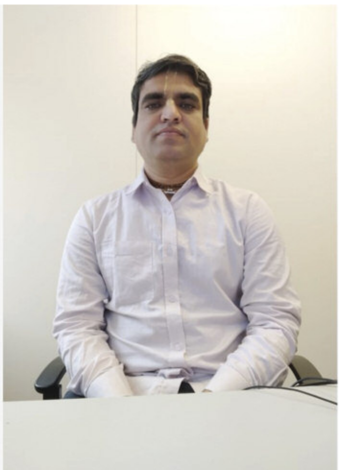
Application deadlines

Deadlines for applications are currently 30 April and 30 September each year.

Since its inception in 1991, more than 790 fellows have participated in the program. In 2023, 19 young scientists began an ERCIM PhD fellowship, and throughout the year, 63 fellows were hosted. The Fellowship Program is named in honor of Alain Bensoussan, the former president of Inria, one of the three founding institutes of ERCIM.

http://fellowship.ercim.eu

> “The ERCIM fellowship seamlessly blends technical and interpersonal skill development. I am immensely grateful for the transformative experience that altered the course of my career, opening doors to new horizons and possibilities. It's not just a program; it's a journey that propels you towards excellence.
>
> **Purnachandra Rao MAKKENA**
> Former ERCIM Fellow



ERCIM's Visionary Event on Generative AI

Experts from across Europe gathered on 16 April 2024 in Brussels at the Maison Irène et Frédéric Joliot Curie to discuss the rapidly evolving landscape of generative AI and large language models (LLMs) at the ERCIM visionary event titled "Challenges and Opportunities of Foundational Models and Generative AI for Science and Society."

Benoît Sagot of Inria opened the event with an overview of advancements in large language models (LLMs), focusing on the transformative effects of Transformer architectures. He discussed the trend towards larger models and the need for balancing data diversity with volume. Sagot also addressed concerns about the proprietary nature of training data, legal challenges, environmental impacts, and biases in these models that could reinforce societal stereotypes.

Following Sagot, Cecile Huet from DG Connect, European Commission, outlined the European GENAI4EU Iniative, which promises to boost the EU's AI capabilities with a four billion Euro investment. The initiative aims to enhance supercomputing power, increase high-quality data availability, and support robust algorithmic development across various sectors including healthcare, climate change, and cybersecurity.

Liviu Stirba from DG Research and Innovation, European Commission, presented the activity and goals of the European Commission's AI in Science group. He discussed AI's transformative potential in scientific research. He underscored the need for an EU policy framework that optimizes AI use in scientific settings while ensuring competitiveness on a global scale.

In the session "Impact of Generative AI and LLMs on the Sciences", Damien Gratadour of the Observatoire de Paris, explained the use of generative AI in building new brain models for giant astronomical telescopes, emphasizing the potential in fields like planet hunting and observing distant celestial objects.

Dong Nguyen of Utrecht University illustrated how LLMs could revolutionize the social sciences by enabling the analysis of large datasets, which could, for example, reveal trends in public opinion dynamics or track shifts in language use over time.

Mathieu Acher from INSA/Inria/CNRS/IRISA discussed the implications of LLMs in software engineering, highlighting their role in code generation and optimization. Acher pointed out how tools like GitHub Pilot and Llama-2 are integrating LLMs to transform coding, making advanced software development tools accessible to a broader audience.

The event continued with a session on "Generative AI and Future Perspectives" where Seán Ó hÉigeartaigh from the University of Cambridge presented on the need for stringent international cooperation in AI governance, highlighting the social and cognitive risks associated with AI, including the propagation of misinformation and the societal impacts of hate speech.

Haris Papageorgiou of the Institute for Language and Speech Processing discussed the role of LLMs as infrastructure for open science, highlighting both the potential benefits and risks, including issues related to data transparency and model biases. Anastasios Roussos from the Institute of Computer Science, Hellas (FORTH), explored the impact of generative AI in image and video synthesis, discussing both its innovative applications and the ethical concerns it raises, such as job displacement and copyright issues. Abdallah El Ali from Centrum Wiskunde & Informatica emphasized the importance of transparent and trustworthy human-AI interaction, discussing the implications of generative AI on content generation and public trust.

The event concluded with a panel discussion highlighting the necessity of integrating AI-generated content with human oversight to maintain information quality and addressed the critical role of multidisciplinary approaches in advancing AI technology effectively and ethically.

These discussions will lead to the creation of a vision document that could guide European research institutes and the European Commission in setting research priorities.

The event was organised by Han La Poutré (CWI, TU Delft), Vice President of ERCIM, together with Marie-Hélène Pautrat and Joost Geurts (Inria). and sponsored by CWI and Inria.

ERCIM Webinar on AI Standardization

ERCIM organised a webinar on 22 March 2024 on AI standardization in support of the EU AI act, following the European Parliament's approval of the Act on 13 March 2024. This marked the transition to developing harmonized standards, as mandated to the European Committee for Standardization of AI (CEN-CENELEC JTC 21) by the European Commission.

The webinar, led by Lauriane Aufrant from Inria, head of the French delegation to JTC 21, concentrated on the committee's work program and the possible role of ERCIM members in AI standardization. Aufrant detailed the committee's mission to develop technical standards across key areas, aiming for publication by 2025. She emphasized the importance of academia and research institutions in ensuring the Act's implementation is technologically current and socially beneficial.

Aufrant's presentation provided insights into JTC 21's interactions with ISO-IEC and the impact of standardization on science, the economy, and society. The session highlighted the critical role of collaboration in aligning the AI Act's implementation with technological advancements and societal needs.

Introduction to the Special Theme

Extended Reality

by the guest editors Ioannis Chatzigiannakis (Sapienza University of Rome and CNIT), Holger Graf (Fraunhofer IGD), Manos Kamarianakis (University of Crete), and Aris Lalos (ISI)

Extended Reality (XR) represents a transformative paradigm in the realm of human-computer interaction, blending and fusing physical and digital worlds to create immersive and interactive experiences. XR encompasses a spectrum of technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), each offering unique capabilities and applications. At its core, XR enables users to engage with digital content in ways that transcend traditional interfaces, opening-up new possibilities for communication, collaboration, and exploration.

The importance of XR lies in its ability to bridge the gap between the virtual and physical realms, unlocking unprecedented opportunities across a wide range of domains. In fields such as education and training, XR offers immersive learning environments that enable students to interact with complex concepts and scenarios in ways that were previously impossible. By simulating real-world experiences, XR enhances retention, comprehension, and skill development, making it a powerful tool for education and professional training.

In addition to its educational applications, XR is revolutionizing industries such as healthcare, architecture, engineering, and entertainment. In healthcare, VR and AR technologies are being used for medical training, surgical simulation, patient rehabilitation, and telemedicine, improving patient outcomes and enhancing the efficiency of healthcare delivery. In architecture and engineering, XR enables designers and engineers to visualize and prototype products and structures in virtual space, streamlining the design process and reducing costs.

Furthermore, XR is driving innovation in entertainment and media, enabling immersive storytelling experiences that blur the lines between fiction and reality. From interactive VR games to AR-enhanced cinema experiences, XR is reshaping how we consume and interact with digital content, offering new forms of entertainment and engagement.

Beyond its commercial and recreational applications, XR has the potential to address pressing societal challenges, from environmental conservation to social justice. By leveraging XR technologies, researchers and activists can raise awareness, foster empathy, and drive positive change in areas such as climate change, human rights, and cultural preservation.

In summary, XR represents a groundbreaking shift in how we interact with technology and perceive the world around us. By combining virtual and physical realities, XR offers endless possibilities for innovation, creativity, and exploration. As XR continues to evolve, its impact on industries, society, and the way we experience the world will only continue to grow, shaping the future of human-computer interaction and ushering in a new era of immersive experiences.

New approaches that combine advanced AI methods, computer vision and computer graphic techniques enhance the visual representation of 3D scenes and allow for fast 3D photorealistic reconstructions, almost instantly. Such instant 3D reconstructions (resp. instant XR environments) help in re-generating static and dynamic scenes, allow for highest visual fidelity and enable digital restoration of missing geometry or missing material, e.g. within the cultural heritage domain. Those approaches also allow for synthetic training pipelines that enable a better training of neural networks for a diversity of AI domains, such as object detection, classification, 6D pose estimation and XR driven environment perception tasks. Applications here are typically found in the manufacturing, aerospace, automotive, architecture, engineering and construction (AEC) sectors.

Virtual and augmented reality monitoring and planning systems offer innovative solutions for enhancing situational awareness and optimizing processes in various sectors, including transportation and infrastructure. By integrating VR/AR technologies with data analytics and visualization tools, organizations can streamline operations, improve safety measures, and enhance decision-making capabilities. This holistic approach to monitoring and planning represents a significant step forward in addressing the complexities of modern-day challenges.

In traffic environments, the concept of cooperative situational awareness using AR technologies has gained traction, leveraging the connectivity of autonomous vehicles and V2X communication protocols. By enabling real-time information sharing among vehicles, AR systems enhance driver awareness and reduce the likelihood of accidents. This collaborative approach not only improves overall system efficiency but also fosters a safer and more interconnected transportation ecosystem.

Immersive virtual colonoscopy represents a transformative advancement in medical imaging and diagnosis, offering a less invasive alternative to traditional procedures. By leveraging VR technology, radiologists can navigate three-dimensional reconstructions of the colon with enhanced visualization and measurement capabilities. This enables early detection of colorectal abnormalities and facilitates timely intervention, potentially saving lives and improving patient outcomes.

In each of these areas, researchers are pushing the boundaries of XR technology to address real-world challenges and improve outcomes across diverse domains. By harnessing the power of immersive experiences and advanced data analytics, they are unlocking new possibilities for training, education, decision-making, and patient care. As these technologies continue to evolve, the impact of XR on industries and society at large is poised to grow exponentially, driving innovation and shaping the future of human-computer interaction.

Cooperative situational awareness in traffic environments using AR technologies has become increasingly important with the rise of connected autonomous vehicles (CAVs). A new method has been proposed to enhance driver awareness and safety through cooperative information sharing among vehicles. By leveraging V2X communication infrastructures, AR systems enable real-time data exchange, allowing vehicles to relay valuable observations and warnings to one another, ultimately reducing the risk of accidents and improving traffic flow.

In conclusion, XR technologies are driving innovation across diverse domains, from engineering and transportation to medicine and healthcare. This special theme showcases how researchers are tackling complex challenges and revolutionizing the way we interact with information and the world around us by leveraging immersive experiences and advanced data analytics. As XR continues to evolve, its impact on industries and society will only continue to grow, shaping the future of human-computer interaction and opening up new possibilities for innovation and discovery.

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Open Standards for the Immersive Web

by Dave Raggett (ERCIM)

The Web grew exponentially on the back of open standards, rapidly eclipsing proprietary alternatives. The same principle will apply to the Immersive Web. This article introduces W3C's work on related standards and how they fit into the standardisation landscape; key challenges for privacy, accessibility, and scaling; and directions for future work, including Generative AI.

As an old-timer, I helped to coordinate early work on the World Wide Web, including the initial standards for HTTP and HTML. In mid-1994, I proposed a vision for extending the Web to support immersive virtual reality [L1]. Work on VRML sadly didn't quite live up to this vision, but years later computers and networks are hugely better, so the future looks very promising. The Web grew exponentially on the back of widely supported open standards (HTTP, HTML, CSS, JavaScript, etc.), rapidly eclipsing proprietary alternatives. The same principle will now apply to the Immersive Web.

Expected application classes include: shopping, entertainment, education, industry, online meetings and desktop replacement. Smart phones and tablets can be used to show how your new kitchen, or new furniture and decor for your living room would look as an augmented reality experience. You can see how you look in a smart mirror (e.g. your phone) when wearing some new clothes, new shoes, different hair styles, jewellery and glasses, before purchasing them online. For entertainment, you will be able to play VR and AR games for mutual enjoyment with your friends. You will have access to educational experiences that set you tasks to solve in an immersive VR or AR environment. Industry applications will use smart glasses for machine maintenance, smart warehouses, etc. Online meetings that project you and your companions into a shared immersive VR or AR environment will be a vast improvement on today's video meetings. VR and AR will function as a computer desktop replacement, offering unlimited virtual screens via headsets or smart glasses.

Illustration created with DALL-E.

Simple 3D models can be used to interpret video from 2D cameras to create live avatars of people. This was demonstrated in the mid-nineties as a means to reduce the bandwidth for video calls. Today's computers are much more powerful, and can generate detailed 3D animations of people's heads in real-time, including facial expressions, derived using video from the camera built into the laptop or smart phone. People could appear as themselves or as avatars of their own choosing.

Devices include: VR headsets, smart glasses for AR, large 2D displays, glasses-free 3D displays, e.g. microlens array-based monitors that beam different images into each of your eyes; cameras for imaging you and your environment; specialised devices such as stereo and depth sensing cameras, as well as 360 cameras that see in all directions at once; microphones and speakers for audio (including surround sound and spatial audio); orientation, motion and acceleration sensors; games controllers, use of cameras for gaze tracking and hand gestures; and haptic devices, e.g. smart gloves.

W3C is addressing this need with the Immersive Web Working Group (WebXR) [L2], whose participating organisations include Adobe, Apple, Google, Meta, Microsoft, Samsung and many others. WebXR is developing a suite of standards for use by browsers and other software. It provides a variety of modular APIs for access to gamepads, augmented reality overlays, hit test, layers, hand gestures, depth sensing, hyperlink anchors, lighting estimation and so forth. Other W3C Working Groups have developed complementary standards including WebGPU for access to GPU hardware in conjunction with the shading language WGSL; Web Audio, Web Neural Networks, Web Assembly, WebRTC, Web Sockets, RDF/Linked Data, the Web of Things, and many more.

W3C is one of many standards' development organisations with an interest in extended reality. The IEEE VR and AR Working Group developed the P2048 suite of standards, including device and video taxonomies, personal identity, environment safety, immersive user interfaces, mapping virtual objects into the real world, and associated interoperability [L3]. The Khronos Group is responsible for glTF, a JSON-based format for 3D assets, and WebGL, a JavaScript API for rendering interactive 2D and 3D graphics in Web browsers. glTF 2.0 is now available as ISO/IEC 12113:2022 and work continues on extensions, e.g. for lighting. WebGPU is likely to slowly take over from WebGL over a period of years. X3D is a suite of ISO/IEC standards developed by the Web3D consortium, covering graphics formats and

APIs. Universal Scene Description (USD) is an open-source framework for 3D originally developed by Pixar, with support from Adobe, Apple, Autodesk and NVIDIA. Opportunities for open-source developers include work on libraries for software and 3D assets, as well as content creation, e.g. the Babylon.js and Godot 2D/3D engines. Generative AI can be expected to play a major role in the Immersive Web, with the ability to synthesise rich virtual environments from simple prompts and populate them using information from servers and peer to peer connections.

The Immersive Web faces many challenges: how to preserve the user's privacy while offering an optimal user experience, how to provide accessibility for users with physical disabilities, how to decouple applications from the details of devices, how to scale to richer 3D environments, and issues around user fatigue and motion sickness. Hand gestures are a great way to control applications, but risks fatigue over long periods. Noticeable lags in rendering can likewise cause fatigue and motion sickness. In respect to scaling, large 3D assets can take significant time to download, shattering the illusion of an immersive 3D world. This can be mitigated using cloud-based rendering or with level of detail control plus pre-loading libraries of assets, along with an option to substitute and adapt assets based upon their similarity.

To simplify applications and to support accessibility, we need higher-level intent-based models and declarative formats. Application frameworks can help, but without standards, they risk fragmentation into incompatible solutions. Browser support for higher-level models would enable accessibility without the need for applications to know about the user's accessibility preferences.

Websites are independent, and discoverable via search engines and hypertext links. The Immersive Web is likely to be similar with many independent applications. An open question is what would attract businesses to set up in shared virtual worlds as envisaged in Science Fiction novels and movies? For instance, Neal Stephenson's "Snow Crash" (1992) and William Gibson's "Necromancer" (1984). The virtual real-estate is valuable only if there is a commercial advantage to being found in the same vicinity as others, however, unlike the real world, users can effortlessly jump from one virtual location to another, making adjacency less important, thereby emphasising the importance of services the virtual world can offer to its inhabitants, and likewise for real-world high streets threatened by the rise of online shopping.

I would like to acknowledge guidance in preparing this article from my ERCIM colleague François Daoust.

Links:
[L1] https://www.w3.org/People/Raggett/vrml/vrml.html
[L2] https://www.w3.org/immersive-web/
[L3] https://digitalreality.ieee.org/standards

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Nature Based Solutions Multi-scale Intervention Planning Assisted by Extended Reality Technologies

by Ioannis Kavouras, Emmanuel Sardis and Anastasios Doulamis (National Technical University of Athens, Greece)

Visualise today the city of tomorrow! The rapid evolution of the computer graphics along with the accessibility in high-capacity 3D geospatial information have led to the emergence of new opportunities for engineers and scientists to better understand, visualise and design the urban environment.

The utilisation of Expanded Reality (XR) technologies provides advanced and innovative solutions for many urban planning applications. Moreover, Virtual (VR) and Augmented (AR) Realities can be used accordingly for digitising and visualising (i.e. BIM – Building Information Models, and DT – Digital Twins), and navigating the city environment [1]. Thus, these technologies can be proved useful for multiscale intervention planning, including urban and architectural design.

The combination of the aforementioned technologies with advanced algorithms provided by a game engine framework is capable of generating a serious game for real-time intervention planning, inside a virtual environment, which can be implemented by expert users (e.g. engineers, urban planners, architects, etc.) and non-expert (e.g. citizens, district governors, etc.). Through this platform the civil engineers, urban planners, architects, and other designers can generate a BIM model of their area of interest and build a serious game [2] for implementing several alternative solutions at the same time, over the same area. In a similar way, non-experts can propose their own solutions by playing the game and test them in a safe virtual environment. Thus, for each solution it is possible to visualise in real time the architectural, aesthetic, and environmental impact (i.e. the solution may pass the aesthetic criteria but may not be usable for a city area citizens).

Another advantage of the serious game approach, enhanced with XR frameworks, is its usage for attracting citizens to participate in the urban design process [3], even from the early stages of the intervention process. This is significantly important, because it democratises and decentralises the urban planning process by collecting feedback from interested citizens. The VR and AR characteristics can inspire young people, who are experienced with such technologies, and find it a lot easier than older people, to participate in the planning process and provide feedback. For the non-experienced users (i.e. older people), the interaction with the serious game can be achieved by organizing public workshops or seminars, where they can either play the game with the organisers' help, or view the game in some screen and instruct accordingly the player (i.e. a workshop organiser) for the placement of the planning feature (co-designing). Human involvement and visualisation of their suggestions and developments in an urban area increases residents and end users socialising behaviour into more democratic ways for urban planning modifications and transformations in modern cities. Public participation promotes inclusivity and diversity in the planning process, incorporating a wide range of perspectives, needs, and preferences.

Figure 1: The euPOLIS Game's proposed Demo solution for the city of Piraeus.

The euPOLIS Game [L1], which is developed under the EU H2020 project named euPOLIS with GA 869448, is an indicative example of a serious game utilised by AR characteristics. In this game, the player can navigate in the four demo cities of the project (i.e. Piraeus, Lodz, Belgrade, and Gladsaxe) and propose a variety of Nature Based Solutions. To be precise, the player can navigate in the proposed by the euPOLIS project Demo Solution and he can provide feedback in an interactive way by answering in-game questions or filling the respective questionnaire by scanning an in-game QR code. Furthermore, the game provides an empty canvas (i.e. the city as is today) and asks the player to place features, such as trees, benches, etc. For a quick evaluation of the player's solution, the game provides simplified models for calculating basic metrics, such as temperature, humidity, etc.

Figure 1 illustrates the euPOLIS Game's proposed Demo solution for the city of Piraeus in Greece. An area under construction and transformation is applied through the proposed game in city residents and stakeholders for proposing related interventions following suggested Nature Based Solutions (NBS) in the specific area. By actively involving community members in the envisioning and transformation of their area, we can harness collective creativity, local knowledge, and a diversity of perspectives. This collaborative process not only ensures that the final urban plans align with the needs of the community, but also fosters a sense of ownership and pride among residents.

For the development of the final proposed solution (Figure 1) more than 30 participants were involved actively providing their opinions and ideas. The participants were from various age groups from younger (i.e., teenagers) to older (i.e., over 60 years old) people. Each participant designed an intervention solution by added features (i.e., foliage, benches, etc.) from a predetermined pool supporting object related to the needs of the euPOLIS project in a dedicated pilot city area (pocket park in Akti Dilaveri in Piraeus, Greece). For the older people who couldn't use the application, an expert assistant helped them by following and respecting their guidelines. Finally, the proposed solutions were evaluated by a group of experts and the final design resulted by considering the combination of both the environmental impact of green solutions and the activities (i.e., a playground for kids and tables/benches for the parents to sit) that proposed by the majority of the participants.

In summary, today programming technologies provide new solutions for 3D game development, from a real area for navigating and visualising different scenarios of interventions, based on XR technologies, without affecting the actual environment. The proposed game can be used for visualising several alternative solutions that can help the architects, designers, urban planners, and engineers to decide on alternative solutions for an area. In addition, these technologies can be shared with the interested public for democratising and decentralising the intervention planning process. This approach can lead to positive modifications and transformations in modern cities that truly reflect the needs and desires of the people who live in them. Thus, this technology can effectively visualise today the city of tomorrow!

This work is supported by the European Union Funded project euPOLIS "Integrated NBS-based Urban Planning Methodology for Enhancing the Health and Well-being of Citizens: the euPOLIS Approach", under the Horizon 2020 program H2020-EU.3.5.2., grant agreement No. 869448.

Links:

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Touch-Sensing 3D Replica for Augmented Virtuality

by Gianpaolo Palma and Paolo Cignoni (CNR-ISTI)

We introduce a system designed to enhance engagement in VR experiences using sensorised replicas of real objects created through 3D printing. This system lets users interact with physical replicas within the virtual environment while visualising the original object's appearance. Additionally, it facilitates the creation of augmented experiences to manipulate the virtual appearance of the physical replica using personalisation actions, such as painting over the object's surface or attaching additional virtual objects, taking advantage of its tactile feedback.

Virtual reality (VR) technologies have become increasingly affordable and popular in recent years, thanks to advancements in hardware and software. A critical challenge for these technologies is establishing paradigms that enable user interactions as similar as possible to the real world, thereby incorporating physicality into the experience.

To address this challenge, we explore integrating VR consumer technologies with directly manipulating 3D-printed objects to create an interactive and tangible user interface within the virtual environment. The primary objective is to develop a VR system that provides users with a blended virtual/real experience perceived as more accurate and engaging. When interacting with a low-cost physical 3D-printed replica, the head-mounted display (HMD) enhances the user's visual experience despite its appearance differing from the original object. The tactile feedback experienced when touching the replica, combined with its interactivity and the high-quality visuals provided by the HMD, significantly enhance immersion and the user's emotional impact. Following the reality-virtuality continuum taxonomy [1], we propose an augmented virtuality experience centred on interactive and touch-sensitive 3D-printed objects.

The proposed system meets three requirements. The first is to enhance the visual appearance of a low-cost physical replica of an artefact by using a VR device, specifically a HMD, to overlay the faithful appearance of the original object virtually onto it. The second requirement aims to enhance the user's emotional impact by enabling them to physically manipulate the replica in the virtual environment, leveraging touch feedback. The final requirement focuses on enhancing user immersion and engagement by allowing the personalisation of the replica through changes in its virtual appearance when touched, facilitated by a physical personalisation palette. To fulfil these requirements, we have designed a system comprising custom hardware components and a software library [2].

The proposed hardware setup integrates various devices. The primary device is the HMD, which provides the visual VR experience and tracks the 3D-printed replica in the VR environment. We utilised the HTC Vive and its extension, ViveTracker, for real object tracking. Additionally, we integrated the HMD with LeapMotion to enable robust active hand tracking. Subsequently, we developed a reusable 3D-printed support to mount physical replicas of different objects onto the ViveTracker, allowing their tracking within the HMD's working area. A physical palette equipped with customisable buttons is attached to the 3D-printed support, enabling users to select the desired type of personalisation to apply to the virtual object's surface. Finally, an electronic controller with capacitive touch sensing detects when the user touches the replica and the personalisation palettes.

The software library, distributed on both the replica hardware and the PC running the experience, collects all data the hardware devices generate. It calculates the surface position when the user touches the replica and visually presents this information to the users. Developed within the game engine Unity, the software employs a custom script to manage Wi-Fi communication with the capacitive touch-sensing controller.

Our system utilises a client-server architecture, with the server operating on the controller and the client embedded within the Unity application. Once the connection is established, the

Figure 1: (Left) Photos of the system hardware. (Centre) Example of an interactive session in the virtual environment. (Right) Photos of the user during the interactive session showed in the centre.

server sends messages whenever there is a change in the touch status over the replica or the palette buttons. The actions associated with each palette button are configurable within the Unity application. For each touch event on the replica, the script determines the surface position for changing the appearance. This process involves a simple ray-casting procedure against the 3D model of the replica. Each ray originates from the position of the index fingertip detected by the Leap Motion sensor.

We have identified three primary directions for casting these rays based on common finger-movement patterns. The index distal phalanx defines the first direction, which enhances the detection of contact points when the user touches the surface with the index finger close to the surface normal vector. The second direction is determined by the line of view connecting the index fingertip to the user's head, resulting in more robust detection when the user touches the surface with the hand palm in an orthogonal position with respect to the view direction. Lastly, the hand palm defines the third direction, which enhances robustness when the user touches the replicas on the silhouette. Through the designed personalisation palette, users can virtually paint over the replica's surface using their index finger as a brush or attach additional virtual objects onto the surface. The palette buttons enable users to select paint colours, choose objects to attach, or undo previous actions. After selecting an action, when the user touches the replica, the system applies the chosen colour to the virtual object's surface or positions the selected object at the touched point using the normal vector for coherent orientation.

Feedback from end-users indicates that the virtual experience was exciting and engaging, thanks to the integration of tactile feedback from the physical replica and visual feedback from the virtual replica through personalisation actions. Users found their interactions natural and fascinating, especially as they became more accustomed to navigating the system. Expressly, the tracking and visualisation of the user's hands in VR were noted for enabling a level of interaction and accuracy during personalisation actions that would have been otherwise difficult to achieve.

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VOXReality: Voice-driven Interactions in XR Spaces

by Moonisa Ahsan, Irene Viola and Pablo Cesar (CWI)

VOXReality is an ambitious project funded by European Commission, focusing on voice-driven interactions by combining Artificial Intelligence (AI), Natural Language Processing (NLP) and Computer Vision (CV) technologies in the Extended Reality (XR) use cases of VR Conference, AR Theater, and AR Training. We will develop innovative AI models that will combine language as a core interaction medium supported by visual understanding to deliver next-generation XR applications that provide comprehension of users' goals, surrounding environment and context in mentioned use cases.

VOXReality [L1] is a European research and development project focusing on developing voice-drive applications in XR. It aims to facilitate the convergence of NLP and CV technologies in the XR field. Our first use case is VR Conference that aims to support virtual assistance in navigation and real-time translation facilitate networking and participant interactions. The second use case is Augmented Theater that will combine language translation, audiovisual user associations, and AR VFX triggered by predetermined speech which will be driven by VOXReality's language and vision pretrained models. The last use case is the Training Assistant with audiovisual spatio-temporal contexts awareness allowing better training simulations in AR environments.

Our goal is to conduct research and develop new AI models [1] to drive future XR interactive experiences, and to deliver these models to the wider European market. These new models will address above mentioned three use cases: human-to-human interaction in unidirectional (Augmented Theater) and bidirectional (Virtual Conference) settings, as well as human-to-machine interaction by building the next generation of personal assistants (Training Assistant). VOXReality will develop large-scale self-supervised models that will be fine-tuned to specific downstream tasks with minimal re-training.

Along with technical advancements, one of the crucial contributions is understanding user needs and leveraging this knowledge to develop innovative solutions that enhance the user experience. This is where Centrum Wiskunde & Informatica (CWI) comes with leading contributions in human-centric design approaches and dialogue system development. The scientific researchers from Distributed & Interactive Systems (DIS) group at CWI are sharing their expertise in gathering user requirements for the project shaping the user experience and design and also contributing to developing large-language models to support dialogue systems [2] within the applications of the project. We actively engage with users, collecting feedback and insights to ensure that our XR interactions align with their needs, preferences, and expectations resulting in high-quality user requirements. This human-centric approach ensures that our XR interactions are not only technologically advanced but also user-friendly and intuitive.

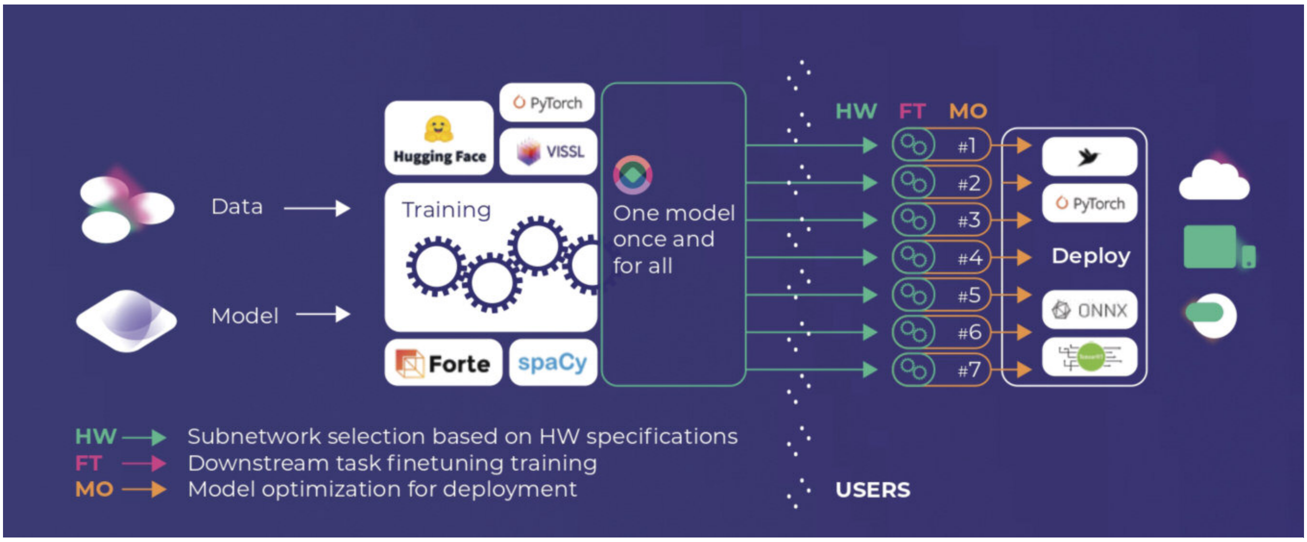

Figure 1: Lifecycle of VOXReality AI Models. VOXReality will follow an economical approach by employing the 'one-train-many-deployments' methodology. 1) Design a model able to perform various tasks; 2) Train the model on a large, diverse dataset; 3) Extract sub-networks based on their deployment hardware target; 4) Fine-tune the extracted model; 5) Perform model optimization.

The project consortium comprises ten partners, i.e. Maggioli (Coordinator), Centrum Wiskunde & Informatica (CWI), University of Maastricht (UM), VRDays, Athens Festival (AEF), CERTH, Synelixis, HOLO, F6S and ADAPT, mainly from the Netherlands, Italy, Greece, Austria and Germany, spanning from research, academia, industry and SMEs sectors. VOXReality started on 1st October 2022 and is expected to finish on 30th September 2025, with a total duration of three years.

We are also focusing on making sustainable and resource-friendly contributions to the XR community. Therefore, VOXReality aims to further extend the use cases and the application domains by funding five partners' projects through OpenCalls+ (OC) worth 1 million Euro funds, where the maximum amount to be granted to each third party is € 200,000. The objective is to ensure reproducibility and repeatability of our research findings, promote open data and interfaces standardisation, avoiding narrow de-facto standards and demonstrate clear and efficient integration paths for the European industry uptake. Moreover, these OpenCalls+ (OC) will focus on building XR applications deploying the VOXReality models based, to demonstrate the clear integration path of the VOXReality pretrained models across the EU SME ecosystem.

In addition to our proof-of-concept of R&D demonstrations and OpenCalls, the expected results of the project include scientific publications, articles, blog posts, and community outreach efforts which can be found on the official website [L1]. Through these avenues, we share our findings, insights, and technological breakthroughs with the global XR and AI communities, fostering collaboration and knowledge exchange.

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VOXReality Team members, at the General Assembly of the project hosted by CWI, Science Park, Amsterdam.

VR2Gather: A Platform for Adaptive Multiparty Social XR Communication

by Irene Viola, Jack Jansen, and Pablo Cesar (CWI)

Extended Reality (XR) telecommunication systems promise to overcome the limitations of current real-time teleconferencing solutions, by enabling a better sense of immersion and fostering more natural interpersonal interactions. To achieve truly immersive communication, high-fidelity representations of our own bodies and faces are essential. Enter VR2Gather: a customisable end-to-end system to enable multi-party communication with real-time acquisition.

The future of media communication is immersive. XR technologies can overcome the limitations of current telecommunication systems by offering enhanced realism, better sense of presence, higher degree of interactivity, and more naturalness in remote social communication. The current commercial solutions for immersive teleconferencing, however, all employ synthetic avatars to represent their users. Ranging from low-fidelity, cartoonish representations, to sophisticated avatars that are designed to mimic our appearance, these solutions nonetheless offer low realism, appear artificial, and can lead to the uncanny valley feeling [L1].

Another solution is to directly capture and transmit photorealistic representations of the users in 3D, using volumetric media, similarly to what we already do in traditional videoconferencing. Several solutions are available nowadays to achieve volumetric video capture, using either commercial 3D sensors [L2] or Ai algorithms to generate 3D contents from traditional videos [L3]. However, such media contents require large amounts of data: for example, an uncompressed 30 frames per second (fps) point cloud video with one million points requires around 5 Gigabit per second (Gbps). Thus, to enable remote communication, we need to lower the bandwidth requirements by orders of magnitude. We can do so by using compression solutions, or by adaptively transmitting the parts of the contents that are of interest for each user, thus tailoring the delivery around each participant's needs. Thus, we need a system that can properly handle the capture, delivery, and rendering of such data in an efficient way. This is what VR2Gather aims to do: to provide an end-to-end system for volumetric real-time communication, that can enable social XR experiences for various sectors, such as healthcare, education, entertainment, and cultural heritage [1].

The system is open-source and customisable, so that different capturing setups, transport protocols, and rendering applications can be selected. It comprises different modules: a capture module, which produces a stream of time-stamped point clouds; a tile module, which splits point clouds into parts, which can be processed separately to enable parallelisation, along with user and network adaptation; an encode module, which compresses the data for more efficient transmission; a transport module, with three different implementations (direct TCP, socketIO, DASH) for transmission over the internet; a receive module that takes the transmitted packets; a decode module that decompresses the packets into point cloud data; and finally, a render module that displays the received data.

Figure 1: VR2Gather is used to enable a shared celebration for CWI 75 anniversary in 2021, complete with a (virtual) cake.

We have demonstrated the use of VR2Gather over several use cases. The first experience was around cultural heritage [L4]. Current museum experiences offer very limited interaction with the artefacts on display, not to mention all the collection pieces that are not displayed because of space limitations or other constraints. The VR2Gather platform was used to present the visitors of the Netherlands Institute for Sound and Vision museum with a costume from the collection, historically worn for a pop performance. Each user could interact with the costume and wear it while recreating the historical

Figure 2: VR2Gather is used to enable remote doctor consultation using consumer-grade phones, over 5G network.

performance, for example by playing instruments and singing on stage [2].

The second experience was around connecting with others while being apart [L5]. In particular, we showed how our VR2Gather platform could be used to bring people together and share a virtual cake slice. Our setup included a specific capturing system for the cake itself along with the users, which were able to chat and interact in real time while being located in different cities.

The last experience was around remote consultation with doctors [L6]. Meeting remotely in an immersive environment opens new possibilities for healthcare, for example by reducing the amount of time patients spend travelling to the clinic and waiting for their appointment, and by enabling people with mobility impairments to access healthcare advice in real time, while waiting for the healthcare personnel to be dispatched on site. However, patients might not have access to high-end volumetric cameras, or stable connections. Thus, we demonstrated the consultation using a consumer-grade phone to acquire a volumetric representation of the patient, which was transmitted over 5G network.

This work was supported through "PPS-programmatoeslag TKI" Fund of the Dutch Ministry of Economic Affairs and Climate Policy and CLICKNL, the European Commission H2020 program, under the grant agreement 762111, VRTogether [L7] and the European Commission Horizon Europe program, under the grant agreement 101070109, TRANSMIXR [L8].

Links:
[L1] https://www.wired.com/story/gadget-lab-podcast-630/
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Bridging Virtual and Physical Worlds through AI

by Fabio Carrara (CNR-ISTI)

Immersive and user-friendly experiences will win the Extended Reality (XR) game in the long run. However, setting up good VR/AR scenarios often requires manual asset authoring, which is realistic just when dealing with a limited number of predefined objects and scenes. The Social and hUman ceNtered (SUN) XR project is investigating low-cost, yet effective, solutions to create links between a physical environment and its corresponding one in the virtual world.

The main gateway to our digital life is still the smartphone, but as technology evolves, we are witnessing a shift towards more immersive and seamless experiences. We spend several hours on the smartphone, utilising its communication, entertainment, and productivity capabilities. However, there are scenarios and tasks where the limitations of the smartphone form factor and interface become clear. XR could fill the gap in scenarios where other interfaces cannot be adopted, offering a more intuitive and immersive way to interact with digital content and information by blending the virtual and physical worlds.

The SUN XR project [L1], funded by the European Commission within the Horizon Europe program and uniting forces of 18 partners from eight countries, aims at exploring the potential of XR in a new era of digital life that better integrate and is symbiotic with the "analogue" life. Specifically, the project focuses on demonstrating how new XR technologies can improve social well-being in diverse contexts, such as healthcare and work environments.

Current XR technology is still in its infancy; setting up a VR or AR experience is a complex and time-consuming task, often requiring digital artists to manually author assets to support interactions with limited, controlled, and non-personalised scenes and objects. One of the objectives of the SUN XR project is to improve the acquisition and understanding of the physical world surrounding us, thus facilitating the transition between the users' physical and virtual environments for general and personalised XR experiences. AI plays a crucial role in achieving this goal; the vast leaps in semantic understanding of the world in open and unconstrained settings can revolutionise how we interact with the digital world and make XR experiences more immersive and user-friendly.

In this context, the CNR-ISTI team is developing novel AI-based methodologies and tools for open-world semantic understanding and multimodal interaction with general environments and objects through sensor streams commonly available in XR devices, i.e. RGB and depth video streams. Two main problems are currently being pursued: understanding dynamic objects (via open-vocabulary object detection) and environment (via scene understanding and 3D reconstruction) semantically. These two tasks could provide the foundation tools for supporting more natural interactions between the user and XR apps.

For the understanding of dynamic objects, open-vocabulary object detection and segmentation models [1] provide a fast

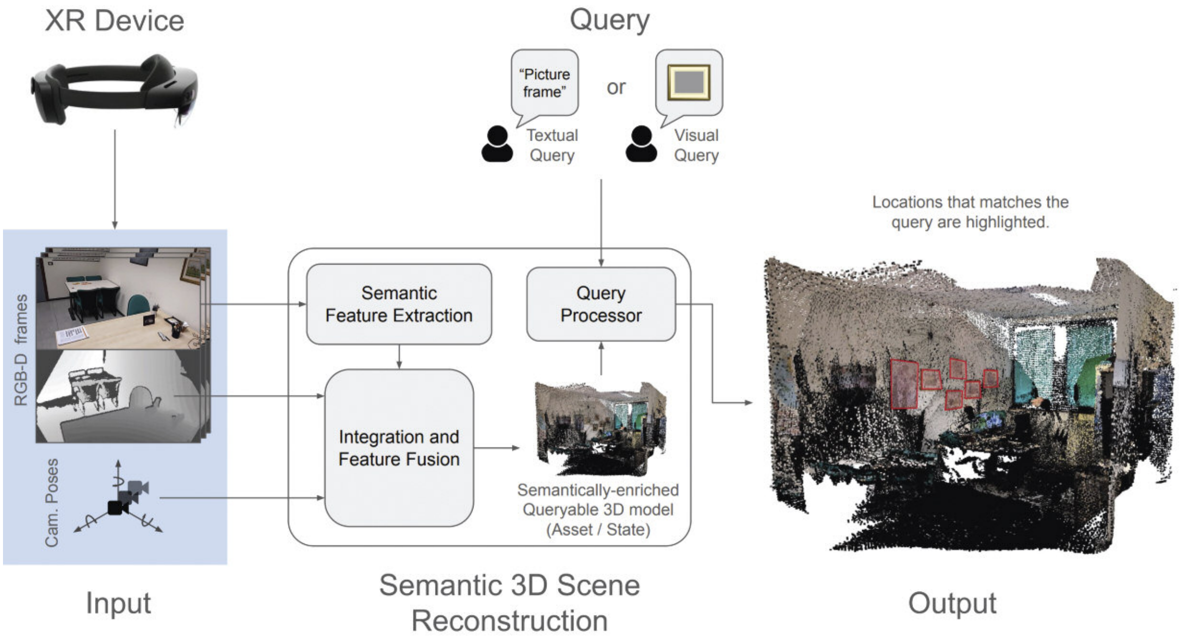

Figure 1: High-level scheme of a semantic-enriched 3D reconstruction pipeline. Semantic understanding is performed on RGB images using state-of-the-art foundation vision-language models and integrated into 3D assets. The user can then interact with its surrounding by textual (e.g. transcribed from speech) and visual (e.g. by gazing, pointing, or external image resources) queries in an open-world setting.

way to locate and recognise objects of interest in the environment without the need for a predefined set of classes. These models exploit the power of general multimodal representations to match regions of the input image with a textual query provided at inference time by the user. This allows for a more natural and flexible interaction with the environment, as the user can ask for objects of interest without the need to know their names in advance. However, open-vocabulary models still have limitations in scenarios where fine-grained object recognition is required, as demonstrated by our current research on evaluating such models in fine-grained description understanding [2, L2]. We deem fine-grained understanding crucial to adapt to complex environments. Our results show that the primary source of errors in fine-grained open-vocabulary detection is the misalignment between the textual query representation and the visual features of the objects, which require more complex matching mechanisms to be solved and are currently under investigation.

For the understanding of the static environment, we are investigating solutions that integrate vision-based multimodal semantic representations (e.g. coming from CLIP-like models [3]) into 3D reconstruction pipelines, providing a semantically-aware 3D representation of the environment that can be queried by free-form natural language queries or even visual queries. Users could ask for objects or scenes of interest via speech and interact with the environment through visual queries, e.g. by gazing or pointing at objects or scenes of interest (see Figure 1). We are currently working on integrating these models into a 3D reconstruction pipeline based on RGB-D data from available AR/VR devices. Current limitations are related to the fusion of multimodal representations from different viewpoints into a coherent 3D representation of the environment, often due to the lack of fine geometric information in the input data, and in making the pipeline efficient and scalable.

We will demonstrate the potential of these AI-based methodologies in two pilots. The first one concerns safety training and innovative cooperation in a manufacturing workplace. The proposed XR systems will provide a more immersive and interactive training experience, allowing workers to interact with the physical environment while receiving real-time feedback and guidance on safety guidelines, such as PPE usage and safe working practices, and a more streamlined overview of the machines and tasks status in the workplace. The second pilot concerns using XR to facilitate interaction with motor- or communication-impaired people. Our semantic 3D reconstruction pipelines and multimodal interaction will allow for a personalised and more familiar immersion in the virtual environment, thus improving the user's communication with their relatives and overall social well-being.

Links:
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[L2] https://lorebianchi98.github.io/FG-OVD/

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Creating High-quality 3D Assets for Realistic XR Solutions

by Marco Callieri, Daniela Giorgi (CNR-ISTI), Andrea Maggiordomo (University of Milan) and Gianpaolo Palma (CNR-ISTI)

Successful Extended Reality (XR) applications require 3D contents able to provide rich sensory feedback to the users. In the European project SUN, the Visual Computing Lab at CNR-ISTI is investigating novel techniques for 3D asset creation for XR solutions, with 3D objects featuring both accurate appearance and estimated mechanical properties. Our cutting-edge research leverages on Artificial Intelligence (AI), computer graphics, and modern sensing and Computational Fabrication techniques. The application fields include XR-mediated training environments for industries; remote social interaction for psychosocial rehabilitation; and personalised physical rehabilitation.

One of the essential components of an XR application is the 3D environment, which is populated by 3D assets, i.e. 3D digital models specifically prepared for use in the application. 3D assets are fundamental to the interaction between the user and the virtual/augmented world. Therefore, the quality of assets is pivotal to the quality of the user experience.

The European project SUN – Social and hUman ceNtered XR [L1] is investigating techniques for high-quality 3D asset creation, by improving either the quality of existing assets or the very process of 3D asset creation. The goal is to populate XR applications with 3D content featuring faithfully reconstructed geometry and appearance, and augmented with estimates of physical and mechanical properties, such as inertia properties. The SUN project started in December 2022, led by the National Research Council of Italy, and involves 18 European academic and industrial partners.

Photogrammetry, due to its versatility and cost-effectiveness, is the most-used technique for the rapid creation of 3D models from real-world objects. It was then a natural choice to address the issues arising in this digitisation workflow. The quality and completeness of the 3D reconstruction depends a lot on the quality of the input photos. Problems such as specular highlights hide the local information needed by the photogrammetric process, resulting in noisy geometry or areas missing in the 3D reconstruction. We thus developed an AI technique to correct, in the input photos, those local visual problems that affect the photogrammetric pipeline. By training a CNN with examples of rendered images of objects with and without specular behaviour, it was possible to obtain a network able to correct the regions of the input images affected by specular highlights, or just to detect them (to mask them out in the photogrammetry software). This approach of pre-processing the input dataset works independently from the software used in the 3D reconstruction, preserving the original working pipeline, and can be easily extended to correct other common problems of the input photographic dataset.

In 3D assets created through photogrammetry, the colour information is generally managed as a texture map generated by the projection of the input photos. This process, however, can often cause visual artefacts due to small projection errors, local geometry inconsistencies, and difference in the illumination in the input images. The only solution is to correct the final texture, but it is a tedious process that requires specific skills. We developed an AI-based inpainting tool [1] that works interactively, providing a paint interface to make it possible for the asset creator to easily and quickly correct local errors in the current texture (Figure 1). We are working on a more automatic process, where visual errors are automatically detected and inpainted.

Finally, we are working on a technique for acquiring the physical properties of a 3D object, such as its centre of mass and

Figure 1: The AI-based inpainting tool can be used to locally correct errors in texture maps using a paint interface.

inertia tensor. In the realm of 3D data acquisition, the focus is typically on capturing the shape and appearance of objects; however, when it comes to creating truly immersive interaction experiences within an XR environment, the physical properties of 3D objects such as mass distribution play a fundamental role, as they support the simulation and rendering of plausible physical behaviour and realistic feedback to humans. Many earlier efforts to acquire mechanical properties either made assumptions about a uniform and well-known object density, or demanded costly laboratory setups. Our challenge is achieving precise and dependable estimations of an object's physical properties from multimodal data obtained from inexpensive hardware sources. Our technique leverages a novel acquisition device featuring an image acquisition box, a sensorised gripper for controlled object manipulation, and a 3D-printed object with controllable mass distribution for generating training data. AI techniques and data fusion algorithms are under study to learn the expected inertia tensor and other relevant physical characteristics that best match the anticipated sensor readings.

The techniques described above will find application in different scenarios. A first scenario is developing effective XR applications for training the workforce in industries, thus answering the pressing demand for continuous workforce upskilling and reskilling. The fast virtualisation of the environments where industrial procedures take place, and the rendering of physical interaction in XR, would enable the creation of a safe yet realistic environment for training for safety and security procedures, and for practicing real-time decision-making in potentially dangerous situations.

As a second scenario, curated 3D assets for XR environments can support rehabilitation, both for psychosocial and physical issues. Novel techniques for high-quality 3D asset creation would support the variability and adaptation of exercises to the patients' needs, by giving therapists a means to rapidly enrich the virtual scenario with objects from the physical world. Also, the recorded data about patients can be augmented with information about the physical interaction with manipulated 3D objects, to assess progress during treatment.

A realistic XR environment cannot prescind from assets generated from real-world objects, but this digitisation process is currently a bottleneck. Beside the objective of obtaining better 3D models, our work in the SUN project aims at streamlining this process in a way that does not disrupt the standard tools and procedures already established in the field, to make the creation of XR environments cost-effective and scalable.

Link:
[L1] https://www.sun-xr-project.eu/

Reference:
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Spatio-Temporal Reconstruction of Large Environments with Artificial Hallucinations

by Marco Di Benedetto, Giulio Federico and Giuseppe Amato (CNR-ISTI)

The power of Generative AI is employed towards a detailed reconstruction of large environments, overcoming short-range and sparsity of common techniques with spatio-temporal 3D diffusion models.

In the rapidly evolving landscape of Extended Reality (XR), the Social and hUman ceNtered (SUN) XR project [L1] emerges as a pioneering endeavour to redefine intuitive 3D data acquisition solutions, promising digitally immersive experiences with unprecedented realism. Spearheaded by a collaborative effort involving esteemed institutions across Europe, SUN aims to set new benchmarks in the creation of physically convincing digital 3D models while facilitating seamless integration with real-world objects.

The SUN XR project boasts a consortium of leading research institutions including the Italian National Research Council (CNR), University of Amsterdam, ETH Zurich, University College London, and the University of Rome Tor Vergata. Taking place across various locations in Europe, this ambitious initiative represents a concerted effort to address the pressing need for advanced 3D data acquisition techniques in the realm of XR.

At its core, the research endeavours of SUN XR are fuelled by a quest to bridge the gap between virtual and physical realities, ushering in a new era of immersive experiences that blur the lines between the two realms. The project commenced its ground-breaking work with a comprehensive vision to revolutionise XR applications through cutting-edge advancements in 3D data acquisition.

Central to the mission of the SUN XR project is the development of intuitive solutions that enable the acquisition of 3D models with unparalleled fidelity and realism. By incorporating crucial physical properties information and devising automated mechanisms for seamless integration with real-world objects, SUN seeks to empower creators with powerful tools to unleash their creativity in XR content creation.

The techniques employed within the SUN XR project represent a convergence of state-of-the-art methodologies from computer vision, machine learning, and sensor fusion domains. In this context, the Artificial Intelligence for Media and Humanities (AIMH) laboratory of CNR-ISTI [L2] proposes a ground-breaking 3D diffusion technique [1] that will integrate in an XR session a 3D reconstruction of a real environment that will transcend the limitations of traditional depth cameras and lidars. By harnessing the temporal information encoded in sequences of environmental images and leveraging spatial cues extracted from initial sparse reconstructions (e.g. a 3D

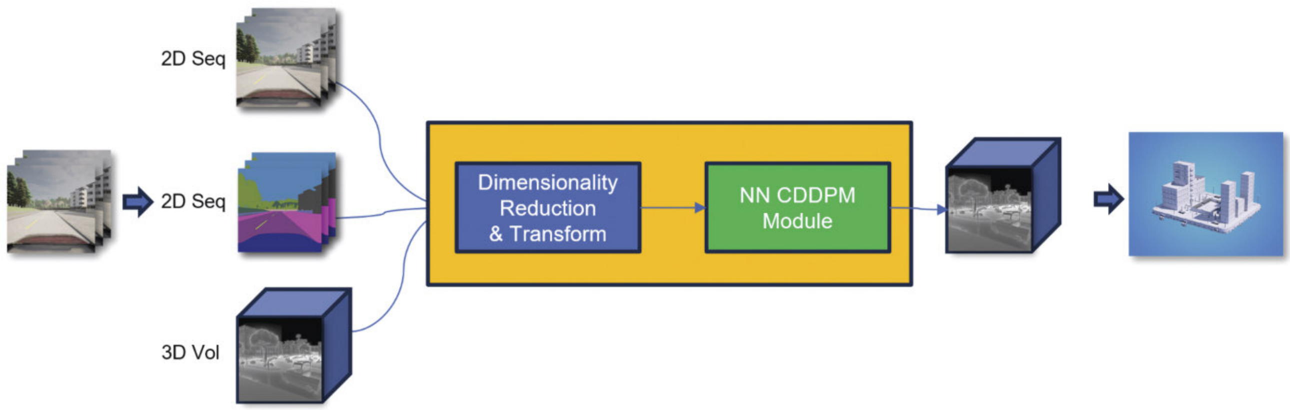

Figure 1: Data pipeline of our spatio-temporal diffusion architecture. Inputs represent an ordered sequence of colour images of the environment, along with a sparse reconstruction of photogrammetric data. Our module will fuse incoming data and hallucinate a 3D representation of the environment with a fine-tuned 3D diffusion generation pipeline.

point cloud consisting of features extracted from a SLAM execution), this innovative approach promises to overcome short-range acquisition challenges while mitigating the sparsity inherent in long-range lidar data. The fusion approach of temporal and spatial information will lead to the definition of a modular 3D denoising diffusion probabilistic model, able to generate missing parts of the scene by hallucinating data that has been precedently learned in a similar scenario (see Figure 1).

To this end, we used a sophisticated third-party driving simulation engine, meticulously crafted to replicate real-world scenarios with high fidelity. The engine is capable of generating 3D colour images, capturing the nuances of light, texture, and perspective to imbue virtual environments with a sense of palpable realism. These images served as the foundation upon which our 3D diffusion model would be trained, providing rich visual data essential for understanding the intricacies of the virtual world.

Complementing the visual data were Signed Distance Field (SDF) volumes [2], a powerful representation of spatial information that formed the backbone of our 3D mesh generation process. By encoding the distance from each point in space to the nearest surface, these volumes facilitated the creation of detailed, geometrically accurate mesh models, ensuring that our simulations faithfully captured the physical attributes of the environments they sought to emulate. The final dataset will be soon made available to the general public.

The innovative technique presented heralds a transformative leap in the realm of XR experiences, promising to revolutionise the way we interact with virtual environments. At its core lies the capability to reconstruct the surrounding environment in near real time, leveraging a fusion of cutting-edge technologies to capture intricate details and seamlessly hallucinate missing elements. The end result is a virtual structure of high fidelity and completeness, meticulously crafted to mirror its real-world counterpart with as much accuracy as possible.

Looking ahead, the future activities of the SUN XR project are poised to build upon its early successes, with a roadmap that encompasses further refinement of 3D data acquisition techniques, extensive validation through real-world deployment scenarios, and strategic collaborations with industry stakeholders to drive technology transfer and commercialisation.

In conclusion, the SUN XR project stands at the forefront of innovation in 3D data acquisition for XR, poised to redefine the boundaries of digital immersion and pave the way for a future where virtual experiences rival, and perhaps even surpass, their physical counterparts. With a multidisciplinary approach, unwavering commitment, and collaborative spirit, SUN XR is poised to shape the XR landscape for years to come, leaving an indelible mark on the fabric of digital reality.

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CONTINUUM, the French Research Infrastructure for Collaborative Interaction and Visualisation

by Alexandre Kabil (Université Paris-Saclay, CNRS, Inria), Ronan Gaugne (Univ Rennes, Inria, CNRS, IRISA), Michel Beaudouin-Lafon (Université Paris-Saclay, CNRS, Inria)

The French National Research Infrastructure CONTINUUM is a unique consortium of 30 platforms located throughout France for advancing interdisciplinary research between computer science, the humanities and social sciences. Through CONTINUUM, 37 research groups develop cutting-edge research focusing on visualisation, immersion, interaction and collaboration, as well as human perception, cognition and behaviour in virtual/augmented reality.

Launched in 2021, the CONTINUUM research infrastructure [L1] features 30 platforms ranging from large immersive CAVEs to ultra-high resolution wall-sized displays combined with a variety of sensors to capture users' activity and enable rich interactions (see Figure1).

CONTINUUM enables a paradigm shift in the way we perceive, interact and collaborate with complex digital data and digital worlds by placing the human at the centre of data processing workflows. The research activities of the network cover human-computer interaction (HCI), virtual, augmented and mixed reality (XR), visual and immersive analytics (InfoViz), collaborative virtual environments (CVE), computer supported collaborative work (CSCW) and High Performance Computing (HPC) for Scientific Visualizations (SciViz).

The infrastructure provides scientists, engineers and industrial users with a network of high-performance visualisation and immersion platforms for observing, manipulating, understanding and sharing digital data, multi-scale simulations and virtual or augmented experiences. The platforms support remote real-time collaboration through dedicated software and hardware. They also feature mobile equipment such as head-mounted displays that can be loaned to external users to facilitate access to these technologies.

CONTINUUM is organised along two axes:

- Interdisciplinary research on interaction, in collaboration between computer science, the humanities and social sciences, in order to increase knowledge and develop new solutions in the field of human-centred computing.

- Deployment of tools and services to meet the needs of scientists and engineers for accessing big data, simulations and virtual/augmented experiences in fields such as mathematics, physics, biology, engineering, computing, medicine, psychology, didactics, history, archaeology, sociology, etc.

The first axis enables a continuum of experiences spanning the wide range of platform capabilities and the diversity of potential users of the infrastructure: device continuity (from headset to screens and CAVEs), interaction continuity (from desktop interaction to full-body tracking), collaboration continuity (from real-time to asynchronous collaboration), and expertise continuity (from novice to expert user). The second axis addresses the needs of three main classes of uses: big and/or complex data (from capture to representation), simulation (from multi-scale physics simulation to real-time interactive environments) and virtual or augmented experiences (from design to controlled experiments) (see Figure 2).

At the technical level, CONTINUUM faces a few technical challenges to support rich collaborative interaction and visualisation across heterogeneous platforms. Interconnecting the

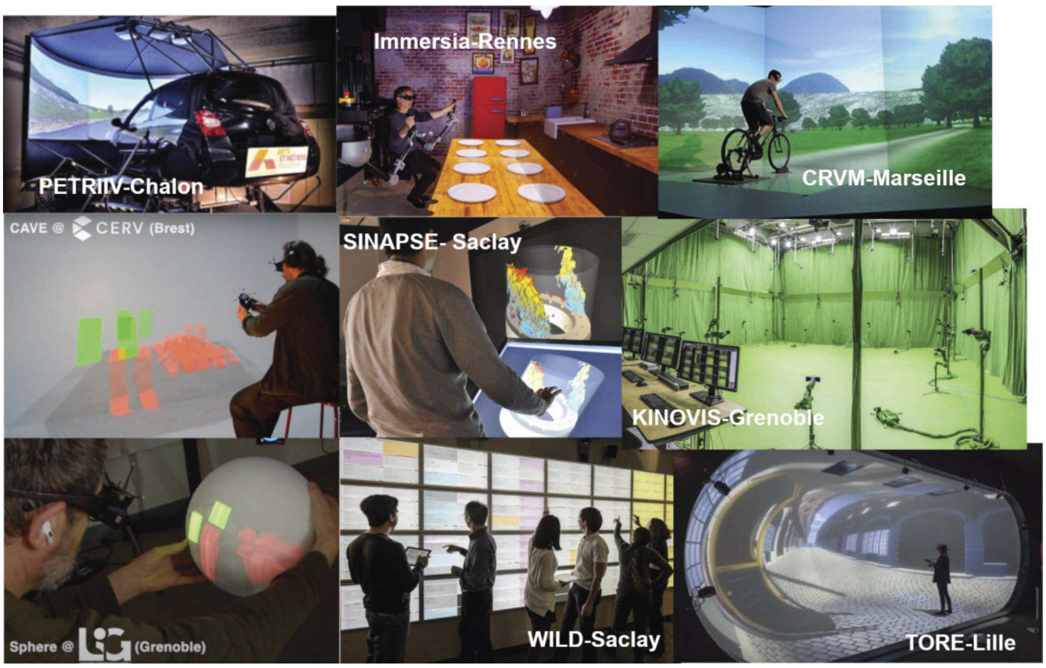

Figure 1: Example of the diversity of CONTINUUM platforms. .© Inria/Photo H. Raguet for WILD picture.

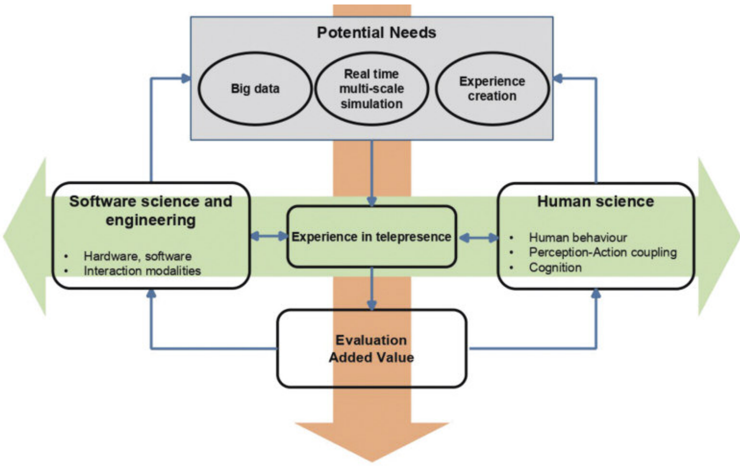

Figure 2: Scope of the CONTINUUM infrastructure.

platforms requires high-bandwidth networking and overcoming the cybersecurity measures imposed by the different partners, as well as agreeing on converting between file formats and protocols that are often incompatible across applications. For example, WebRTC works well for streaming audio and video between web applications running on large wall-sized displays, but is not standard yet for immersive applications and scientific visualisation tools. Coupling motion tracking and biosensor data with virtual environments to let users interact remotely with complex 3D data visualisations generated by a computing cluster while streaming audio and video requires coordination and interoperability at different levels of the infrastructure.

CONTINUUM's broad geographical and scientific coverage enables the dissemination of the network's know-how to the economic and social environment, in collaboration with innovation transfer players. Specific business models are being developed to let both academics and private users access the equipment and the cutting-edge expertise of the partners.

CONTINUUM is led by CNRS [L2], the French National Centre for Scientific Research. Two other national institutes participate in the network: Inria [L3], through the three research centres of Rennes, Grenoble and Saclay, and CEA [L4], through its Saclay research centre; as well as 19 universities and engineering and higher education schools. Over 160 researchers and Ph.D. students from 37 research groups directly participate in the network, and close to 600 Master-level students access the platforms annually.

In summary, CONTINUUM provides a key missing link between the current e-infrastructure of data centres, computing facilities and cloud services on the one hand, and human intelligence and expertise on the other. More than ever, we need collective human intelligence to harness the power of computation and tame the data deluge. More than just a "human in the loop", we need the human to be in control, and we need to provide them with proper tools to exert their control.

For centuries, natural sciences have developed scientific instruments to observe hidden phenomena, conduct experiments and make discoveries. Similarly, CONTINUUM is a digital instrument to explore the digital world. By developing both the instrument itself and using it in a variety of application areas, CONTINUUM will foster interdisciplinary research at an international level to better understand how to interact with the digital world and enable advances in other sciences and engineering fields.

CONTINUUM represents an opportunity to develop a European-scale research infrastructure in the domain of advanced visualisation, interaction, and collaboration in XR following the example of the former FP7 European infrastructure VISIONAIR [1], which gathered 25 partners from 11 countries, and enabled 25 internal projects to improve visualisation and interaction technology protocols.

We are currently running innovative PoCs such as a project to design collaborative and immersive environments for heterogeneous artistic modalities between Immersia-Rennes and Tore-Lille (see Figure 1), and a project on asymmetric collaboration between immersive virtual reality and spatial augmented reality, as shown in the two images on the left of Figure 1, with CERV-Brest and Sphere@LIG-Grenoble.

This work was supported by French government funding managed by the National Research Agency under the Investments for the Future programme (PIA) grant ANR-21- ESRE-0030 (CONTINUUM).

Links:
[L1] http://continuum.website
[L2] https://www.cnrs.fr/en
[L3] https://www.inria.fr/en
[L4] https://www.cea.fr/english

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Enhancing User Experience with Tangible Interactive Systems through Extended Reality

by Asterios Leonidis, Maria Korozi and Constantine Stephanidis (FORTH-ICS)

Recent advancements in Extended Reality (XR) technology, have expanded the scope of potential applications, enabling highly immersive solutions that blend digital and physical elements seamlessly. These developments have introduced applications like ARcane Tabletop and CRETE AR, which offer immersive experiences in gaming, historical simulations, and virtual exploration. Additionally, systems like GreenCitiesXR, Research Assistant, and the Digitised Material Preservation Application leverage XR technology to enrich collaboration and creativity.

Over recent years, XR applications have increased in popularity among researchers, enterprises, and consumers alike. With a continuous flow of new XR devices and accessories entering the market, such as HoloLens, Magic Leap, Meta Quest 3, Apple Vision Pro and many other forthcoming products, the XR field is expected to revolutionise the world of computing.

As a result of these recent innovations, the scope of potential applications has increased substantially, and nowadays it is possible to develop highly immersive solutions that harmoniously integrate digital and physical modalities [1]. XR technologies enhance interaction with real-world digital content, provide contextual information, improve spatial awareness, and deliver personalised experiences. In conjunction with tangible interaction, which enables physical engagement, reduces cognitive load, leverages physical affordances and enhances accessibility, users experience intuitive, memorable interactions that stimulate their senses, promote ease of use and improve user acceptance [2].

Recognising these possibilities, the HCI Laboratory at FORTH-ICS, in the context of the Ambient Intelligence (AmI) Programme [L1], has been developing a series of applications (Figure 1) and artefacts (e.g. AugmenTable [L2]) targeting various domains (e.g. education, culture, entertainment), which aim to leverage these technologies to enrich User Experience (UX) and promote natural and user-friendly interaction.

ARcane Tabletop offers a unique blend of physical and digital elements, providing an immersive multiplayer experience in turn-based board games through XR. Players gathered around a table wear Augmented Reality (AR) headsets and interact with holographic 3D terrains and characters. Each character possesses abilities for dynamic interactions, adapting to various scenarios and rulesets. This hybrid approach retains the

Figure 1: Immersive XR applications developed in the context of the AmI programme.

social and tactile aspects of traditional board games while incorporating immersive virtual enhancements like sound effects and holographic visualisations. Beyond gaming, ARcane enables interactive simulations of historical events (e.g. Battle of Salamis, Battle of Waterloo), allowing players to engage first-hand in strategic battles and better explore historical contexts.

ARgus Designer [3] revolutionises the evaluation of XR applications with its comprehensive toolkit for real-time testing, data collection, and analysis. It streamlines the process and fosters collaboration among experts, enabling assessment of Intelligent Environments (IEs) using devices like the HoloLens2. It also focuses on IE prototyping, crucial for environments in developmental stages that may lack essential elements like smart devices or furniture. This feature underscores its adaptability to varying development phases, ensuring comprehensive evaluation capabilities. In detail, ARgus Designer empowers the research team to meticulously craft virtual experiment scenes, seamlessly integrating digital objects. They can select specific metrics and features tailored to the XR environment, fostering collaborative efforts among stakeholders. During runtime, the team can observe real-time metrics in XR and utilise the ARgus Workstation for experiment control and data collection. Virtual questionnaires further enhance expert supervision and minimise disruptions during evaluations. Post-study, the system facilitates thorough data review and experiment replay directly within the XR environment, enabling comprehensive analysis and iterative improvements.

GreenCitiesXR is a serious game that combines physical and digital elements to promote sustainability and environmental awareness. By allowing players to collaborate and make decisions about city infrastructure, the game not only educates them about the importance of sustainable practices but also provides them with a tangible way to see the consequences of their choices. The use of physical cards representing different infrastructure options (e.g. public transport, LED lighting) adds a tactile element to the gameplay, making it more immersive and interactive. By selecting a card, the city's "green-o-meter" is impacted, and immediate visual feedback is provided through the interactive surface and the accompanying MR glasses. That kind of direct visualisation reinforces learning and encourages players' critical thinking towards more environmentally friendly decisions. For example, in a gaming context when players opt for renewable energy the sky is clear; otherwise, if fossil-based energy is used, the sky gets polluted with smoke. In a more formal context, municipal authorities can use a 3D projected digital twin of the city to visualise policy outcomes, aiding informed decisions for citizen well-being.

Research Assistant constitutes a flexible system designed to support various research processes (e.g. school/university projects, market analyses, literature studies, text classification, etc.). The system augments printed documents with digital information, and allows the addition of virtual bookmarks, labels and notes atop stacks of physical documents. This augmentation is not limited to projection onto paper surfaces, but extends to presenting relevant visual data via wearable headsets to facilitate user exploration and minimise visual clutter on the working area. Additionally, the system features an intelligent digital character projected within the headset, capable of understanding and responding to user commands via text or voice input. Acting as a virtual assistant, it provides on-demand support akin to a physical aid, supporting users throughout the analysis process.

The Digitised Material Preservation Application is an educational tool that integrates printed materials, physical implements (e.g. scissors, glue, chisels, spatula), and digital content to teach the conservation and restoration process of cultural heritage documents, such as maps, in a playful and interactive way. Utilising Mixed Reality, users can visualise the application of 3D printed tools to complete tasks, such as applying a thin layer of glue or replacing a torn part of a vintage map with a piece of washi paper, enhancing the learning experience through immersive visualisation.

Finally, in the field of tourism and culture, CRETE AR [L3] is a system that promotes the virtual exploration of the island of Crete by exploiting cutting-edge XR and tangible technologies. It allows the user to navigate to various points of interest (e.g. cities, monuments, sights) through a combination of digital and haptic interaction. By selecting a point from the 3D representation of Crete, appropriate digital content (e.g. 3D animated models) is projected onto the Mixed Reality glasses, offering a unique interactive experience. For instance, selecting the Cretan wild goat triggers 3D animals to roam areas where encounters are likely, while a larger of a goat appears beside the user, enabling close interaction and detailed exploration.

Links:
[L1] https://ami.ics.forth.gr/en/home/
[L2] https://ami.ics.forth.gr/en/project/augmentable/
[L3] https://ami.ics.forth.gr/en/installation/innodays-2023/

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Interactive XR for Collaborative Distance Education

by Michael Prodinger, Rita Stampfl, Marie Deissl-O'Meara (University of Applied Sciences Burgenland)

The innovative and collaborative Extended Reality (XR) learning environment, which empowers flexible and interactive continuing education, is a characteristic of the first distance learning programmes at the FH Burgenland. With their well-organised module structure, the programmes not only give students the freedom to plan their online and asynchronous coursework independently, but also underscore their commitment to offering a contemporary learning experience through the central role of the XR platform MeetYoo. Features of this platform such as its info-point and virtual fireside chats, promote student interaction and networking with experts. The ongoing interaction that follows, coupled with access to resources without time or space constraints reflects the desire to optimise the learning process and offer students exceptional flexibility and support in their academic and professional journey.

The University of Applied Sciences Burgenland Continuing Education [L1] designs distance learning courses as comprehensive continuing education programmes in a variety of subject areas. A key feature of these courses is their unlimited flexibility: students can begin their studies at any time and the course content is taught online and asynchronously. This methodical approach allows students to plan their studies individually and independently of time and space constraints, thus maximising the learning experience and increasing academic success [1]. Further characteristics that set distance learning apart include unrestricted access to instructional resources and the flexible organisation of study and examination times without the need to be physically present.

Utilising a learning management system (LMS) such as the Moodle learning platform, which provides a wealth of resources such as detailed scripts, videos, audios, interactive learning elements, and self-checks, enhances preparation for exams and fieldwork. This aligns with research indicating that multimedia use not only improves student engagement but also contributes to enhanced learning outcomes. Furthermore, a strong focus is placed on acquiring practical knowledge, which is essential for professional practice and for empowering students to effectively apply theoretical knowledge [L2].

The collaborative XR learning environment makes it possible to expand student networks through interaction in virtual spaces at any time. Kanimozhi [L4] and Donelan et al. [L5] emphasise the potential of collaborative XR learning environments to complement traditional teaching methods and to minimise or, as in the case described, replace physical presence in lecture halls. A large virtual lecture hall for fireside talks with experts and a Walk & Talk area are just two of the features of the collaborative XR learning environment that encourage student involvement and networking. Additionally, open communication is promoted and institutional ties are strengthened by holding a monthly info-point with the course director. The collaborative XR learning environment is the foundation or starting point for students to access the Moodle LMS (Fig. 1). This means that the path to Moodle is always through the XR collaborative learning environment, helping the students to save time, by providing the links to the various resources in the LMS.

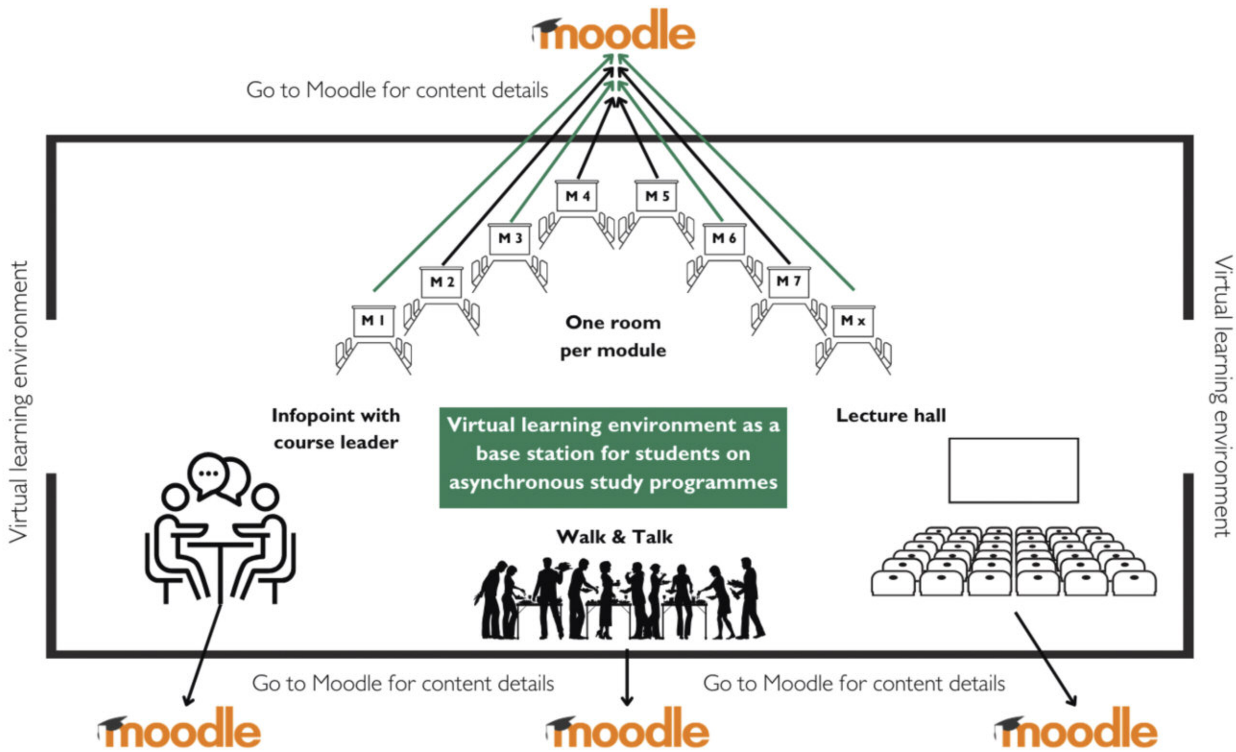

Figure 1: Collaborative XR learning environment as a basis.

There is a large virtual lecture hall, as well as module-specific rooms intended to promote student discussion and idea sharing, in addition to the Walk & Talk area. These permanently available spaces provide flexibility in studies and facilitate both planned and spontaneous academic discourse. Furthermore, they foster the development of learning communities and a sense of community [L6], which strengthens group problem-solving and knowledge sharing. This setup overcomes traditional learning environment limitations, creating a dynamic, interactive space for today's digital student generation.

The programme director is available for direct communication once a month, via the Infopoint in the virtual auditorium in the collaborative XR learning environment, aimed at improving the academic community [L7]. For ongoing assistance, regardless of time or place, students can also email the director or management, ensuring that queries and comments can be handled effectively. The Infopoint's permanent location in the virtual auditorium [L8] signifies the institution's commitment to offering comprehensive student guidance and the importance of flexible communication in modern education. By leveraging technology, this approach meets the expectations of the digital age by improving academic support and student satisfaction.

The Digital Campus's virtual Walk & Talk area is a key interactive space for interdisciplinary exchange, open to students from all academic levels and locations. It encourages knowledge sharing [L9] and collaboration, essential for professional growth and networking. This interactive space responds to the growing digitalisation in education and work, facilitating community formation around common interests and goals. It serves as an incubator for future professional collaborations allowing students to expand their networks, gain multidisciplinary insights, discuss challenges and practical solutions from their field. This informal setup promotes the exchange of ideas and project initiation, crucial in a networked, dynamic work environment where interdisciplinary skills are increasingly valued [L10].

Virtual fireside chats, for instance, offer an interactive, personal discussion environment, bridging the gap of physical distance, while the virtual lecture hall serves as a platform for student-expert interactions and is one way that higher education is becoming more digitally enhanced. This interactive space supports large student audiences, extending access to learning and networking. Featuring experts from different fields in these virtual settings enriches academic content with current expertise and professional insights, facilitating direct engagement with industry-relevant knowledge. These kinds of interactions greatly improve the preparation of students for their future careers by bridging theory and practice [L11].

Developed through meticulous conceptual efforts in close consultation with the provider, the incorporation of a collaborative XR learning environment not only enhances the appeal and practicality of distance learning programmes but also facilitates knowledge transfer and fosters engagement within the academic community. This emphasis on the social dimension, as underscored by the platform, proves to be integral to the success of both the network and the overall programme [L12].

Overall, the combination of asynchronous online learning supported by a comprehensive learning platform and the innovative use of collaborative XR learning environments shows that distance learning programmes create a future-oriented and flexible learning environment that promotes both the academic success and the professional development of students.

Links:

[L1] https://fh-burgenland-weiterbildung.at/
[L2] https://kwz.me/hAV
[L3] https://www.meetyoo.com/de
[L4] http://ijarcs.info/index.php/Ijarcs/article/view/5601/4631
[L5] https://onlinelibrary.wiley.com/doi/10.1002/cae.21928
[L6] https://link.springer.com/article/10.1007/s11528-014-0733-x
[L7] https://kwz.me/hAW
[L8] https://kwz.me/hAX
[L9] http://ieeexplore.ieee.org/document/1039223/
[L10] http://link.springer.com/10.1007/978-3-030-26342-3_14
[L11] https://kwz.me/hAZ
[L12] https://kwz.me/hDC

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Towards Passion-driven Learning in Extended Reality with Meaningful Gamification and Escape Room Games

by Stylianos Mystakidis (University of Patras)

Spatial computing, extended reality (XR) and the Metaverse are emerging technologies with the potential to transform education and training. However, technology-use alone in education without suitable pedagogical strategies and methods cannot guarantee effective learning experiences. Meaningful gamification in the form of escape room games is one viable option to increase sustainable engagement and instil passion in learning.

Spatial computing, XR and the Metaverse are emerging technologies with the potential to transform education and training beyond the capabilities of current learning systems since they enable the creation of powerful, detailed, episodic memories. The human brain treats experiences in 3D virtual immersive spaces in the same fashion as in the physical world. Therefore, it is possible to realistically replicate spaces, objects, and practices in virtual environments.

However, technology-use alone cannot guarantee effective learning experiences. In the era of 3D virtual words or Metaverse 1.0, the first inclination of educational institutions was to build replicas of the physical campuses, schools, auditoria, and classrooms [L1]. Similar moves are observed in the current-iteration Metaverse 2.0 [L2]. While this move is understandable as an exploratory step and has merit in several contexts such as online distance education, the effectiveness of such environments is questionable; is a lecture more effective in a physical auditorium, online via videoconferencing, or in a virtual space?

Conventional learning in XR starts with the observation of 3D visualisations and the manipulation of 3D objects and models. While these methods can be valuable, several efforts have been undertaken to identify taxonomies of effective instructional design methods in AR [L3] and VR [L4]. Deep, long-lasting and transformative learning usually involves three elements: cognitive involvement, the generation of emotions and some form of social interaction [L5].

Gamification is one method that can address the aforementioned cognitive, affective and social domains of learning by integrating playful and gameful elements into the training materials, environment or process [1]. A superficial, structural gamification approach adds a layer of game mechanics such as points, badges and leaderboards on top of learning providing extrinsic incentives and rewards. A more sophisticated and meaningful gamification strategy aims at activating the intrinsic motivation of learners. It uses sophisticated game dynamics and techniques such as narratives, freedom of choice, discovery and reflection to immerse learners to create curiosity and interest to explore and engage with the game mechanics. Notable examples of story-driven gamified XR learning experiences are escape or breakout room games in virtual reality [2] and augmented reality [3]. Escape rooms are games that engage players in adventurous missions, usually to exit from one or more confined spaces. While these live-action games were conceived as a form of entertainment, they can be used to serve a serious, educational purpose.

The “Lost in the Echoes” immersive virtual reality serious escape room game is an example from the realm of a science education, namely physics [2]. Users are briefed about their mission and enter a fictional dungeon (Figure 1). There they engage with sounds, music and acoustics executing various tasks that generate sounds and learning experientially about these concepts as they progress through several levels. These activities realistically simulate learning activities that are being undertaken during a learning programme on the origin of sound and music in a physical science museum. This game can be played in immersive virtual reality headset such as Oculus Quest 3.

Figure 1: Aerial view of one virtual environment of the “Lost in the Echoes” serious VR escape room game.

In physical training settings, clues and evidence can be arranged as an invisible digital layer in objects and specific locations that can be visualised and accessed through mobile devices, smart glasses and mixed reality headsets such as Apple Vision Pro. For example, in the augmented reality serious escape room game "LockED in ShakespeARe's Globe Theatre", a virtual field trip to the famous theatre turns into a thrilling drama when the spirit of the famous author traps learners and challenges their cultural knowledge, communication and cooperation skills [3].

XR escape room games are a useful format that can be applied creatively across diverse fields such as health (e.g. medicine, safety), STEM (e.g. chemistry, mathematics, engineering, programming) and HASS domains (e.g. humanities, language, arts, social sciences). Preliminary results from various experiments [L6] revealed that these learning experiences enable deeper comprehension and improved retention. At the same time, trainers and teachers approved this method and are willing to use them in their courses [L7]. Augmented reality overlays in serious escape rooms can animate any physical setting alive and implement multiple scenarios. A virtual reality escape game can be very effective in distance online educational settings. It provides a relatively short experience around a field, theme, topic, concepts or procedures. In contrast to simple simulations, it creates a fictional, virtual narrative world where learners are the protagonists who are challenged to execute a mission which in relevant and directly linked to the intended learning outcomes. Although pre-designed escape room games can be used as assignments or live classroom activities, in line with the taxonomy of instructional design methods in AR [L3] escape rooms can also be designed by learners as project deliverables to demonstrate their comprehension and creativity.

Links:
[L1] https://kwz.me/hAD
[L2] https://kwz.me/hAF
[L3] https://doi.org/10.1007/s10639-021-10682-1
[L4] https://doi.org/10.1016/j.compedu.2022.104701
[L5] https://doi.org/10.3390/encyclopedia1030075
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Extended Reality Intelligent Assistant for Education

by Filip Škola, Václav Milata and Fotis Liarokapis (CYENS)

This article introduces an intelligent Extended Reality (XR) teaching assistant communicating with the users in natural language. The application uses artificial intelligence (ChatGPT) to understand and communicate with the students using realistic-looking avatars with body language. Teachers can customise the application by adding their slides to be taught or choosing a teaching topic that will be discussed by two intelligent agents.

Thanks to their positive influence on learning and engagement in educational settings, XR technologies have become influential in the field of education. XR, which includes virtual reality (VR), augmented reality (AR), and mixed reality (MR), in combination with traditional teaching methods, can greatly enhance learning by conveying practical experiences to the students. The knowledge acquisition with XR can more easily get beyond teaching theory only, which allows teaching some skills more effectively [1, 2]. However, creating XR applications for educational purposes is currently a complex task demanding XR-specific skills, significant time, effort, and financial resources. The XR4ED EU project [L1] aims to address areas needing improvement to position Europe at the forefront of advanced educational technologies. The project's goals include bringing together the EdTech sector (the field of education technology in Europe) and XR communities and resources to foster innovation and create a central hub (open marketplace) for XR learning and training applications. The XR4ED project has cascade funding and will fund 20 projects, up to €230000. It will support start-ups, small- and medium-sized enterprises (SMEs), and industries active in the education sector, as well as schools, high schools, universities, and vocational education and training (VET) institutions, via two Open Calls, each funding ten projects, with a 12-month duration. Additionally, facilitating the ecosystem of XR technologies and tools for teachers and learners is among the priorities of the project.

One of the major outputs of the XR4ED project is an XR Intelligent Assistant, an AI-powered virtual teacher that interacts with the students in an AR environment created by the Extended Experiences [L2] group in CYENS – Centre of Excellence (Nicosia, Cyprus). The front end of the application consists primarily of a virtual agent (or two agents) represented by avatars, talking in and understanding natural languages and featuring advanced body language. Realistic avatars (from Character Creator 4 [L3]) have been utilised, but the teachers can choose their own. Ready Player Me animation library [L4] was utilised to implement the body language. In an idle state, the avatars show subtle movements such as shifting weight, blinking, and occasional head turns, mimicking the natural resting state of a human. During speech, the body language becomes more pronounced; avatars gesture with their hands, facial expressions, and posture changes. This dynamic range of body language which enhances lip-syncing during the speech facilitates the avatars' lifelike presence and interactivity in the AR space. Communication with the agents stands on

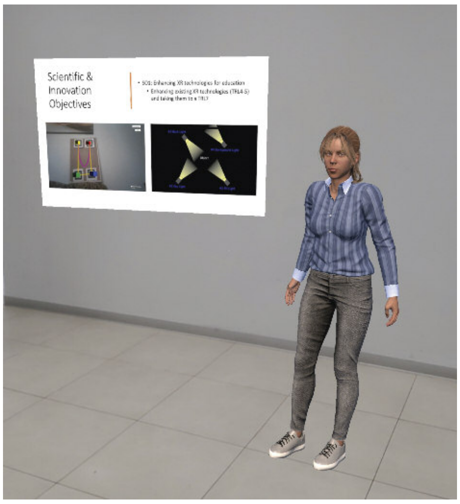

Figure 1: XR Intelligent assistant presenting prepared PowerPoint slides.

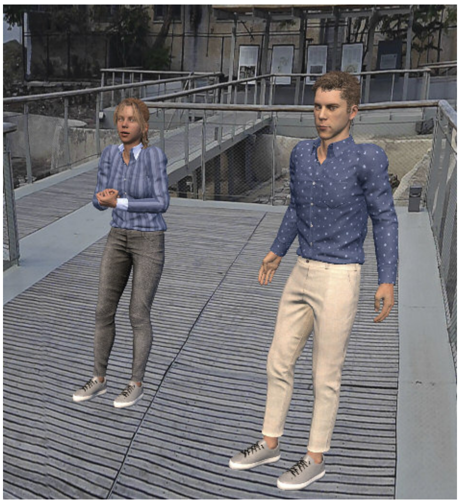

Figure 2: Two intelligent agents discussing a topic in the panoramic image mode.

the speech-to-text (STT) and text-to-speech (TTS) capabilities, both implemented using Azure Cognitive Services [L5]. This allows interaction in several different languages, thus the far-too-common limitation of using English only is not present. TTS also produces visemes that serve to ensure correct lip-syncing behaviour across the different languages.

Most importantly, the spoken input from the user translated into text is fed into ChatGPT [L6], the online large language model (LLM) AI service, which allows advanced forms of natural language communication. This is especially powerful in combination with PowerPoint and video integration. With the PowerPoint presentation, the teachers can use the application to present their slides (Figure 1). The AI capabilities allow presentation of the slides in natural language, while being capable of going into arbitrary depth of individual topics. The students using the application for knowledge acquisition can interrupt the narration at any point and ask the XR assistant questions. Using ChatGPT enhanced with the PowerPoint slides' data, the assistant can answer the questions and continue in the teaching process. The assistant can also navigate within the PowerPoint document and understand references to specific slide numbers. When video or PowerPoint slides are not included, the learners can use the application in a mode where two AI agents are having an intelligent conversation over a teaching topic (Figure 2). The learner can again interrupt these AI agents and ask questions.

Although the application is primarily presented in an AR environment, it offers a panoramic image mode that can optionally be used to surround the user in the XR space (Figure 2). This shift towards VR along the MR spectrum brings more immersion and is especially suitable for certain learning scenarios, e.g. featuring learning about historical sites, natural ecosystems, or other content that is bound to a place. The XR Intelligent Assistant has been implemented on Magic Leap 2 [L7] AR head-mounted display (HMD) and for Android for usage on phones. The former offers a very immersive AR experience, but the cost of the equipment is much higher than that of an Android phone, making the latter a practical choice for a classroom. Nevertheless, implementation for HMDs such as Meta Quest 3 will be performed to extend the target user group. Especially in the "VR mode" of the application (with surrounding panorama), the qualities of the real-world reproduction of the target device no longer matter.

To conclude, the presented XR Intelligent Assistant is an interactive, multilingual, and highly customisable (in terms of adding own teaching materials, personalised avatars, and panoramic images) novel teaching tool that utilises cutting-edge technology from both XR and AI fields. It showcases the possibilities of engaging and dynamic knowledge transfer using XR technology, where the teachers are required to prepare their lecture (e.g. create the slides), but the actual presentation is conveyed by the technology exclusively. However, before the XR Intelligent Assistant can be employed in classrooms, several challenges and issues must be solved. These include topics of privacy, ethics, and regulation. After the practical issues are resolved, the XR Intelligent Assistant bears the potential to significantly transform the process of teaching and learning with technology.

This work has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 739578 and the Government of the Republic of Cyprus through the Deputy Ministry of Research, Innovation and Digital Policy. It has also received funding from the European Union under grant agreement No 101093159. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Links:
[L1] https://xr4ed.eu/
[L2] https://ex.cyens.org.cy/
[L3] https://www.reallusion.com/character-creator/
[L4] https://kwz.me/hAU
[L5] https://azure.microsoft.com/en-us/products/ai-services
[L6] https://chat.openai.com/
[L7] https://www.magicleap.com/magic-leap-2

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Personalised, Context-Aware XR Training Applications Driven by Large Language Models

by George Fatouros and John Soldatos (INNOV-ACTS Limited)

The use of Extended Reality (XR) technologies for industrial workers' training provides immersive and cost-effective learning experiences that improve safety, efficiency, and productivity in the workplace. Nevertheless, most XR-based training applications are based on static and inflexible content, which limits their customisation and personalisation potential. This article introduces a novel approach to developing and deploying XR applications for training industrial workers. The approach leverages Large Language Models (LLMs) and Generative Artificial Intelligence (GenAI) to produce customisable, context-aware, and personalised content that significantly enhances the workers' training experience.

LLM and XR Integration

Industrial training applications of the Industry 5.0 era must be highly personalised and worker centric. This asks for a shift from inflexible "one-size-fits-all" applications to person-centric applications based on content tailored to the workers' preferences and context. The development of such person-centric XR requires novel approaches to the world-building, content-production and flow-control elements of XR systems. In this direction, Artificial Intelligence (AI) can be used to develop context-aware and personalised synthetic data [1], which are integrated with XR-based training applications. The latter leverage AI models like GAN (Generative Adversarial Networks) to generate multimedia content that drives the development of customised cyber representations of industrial training processes. Such approaches increase the flexibility of training applications yet provide limited room for generating content in an interactive way that considers the context, preferences, and experience of the workers.

During the past year, the advent of Large Language Models (LLMs) (e.g. OpenAI's GPT variants, Google's Gemini, Meta's open source LlaMA2) and Generative AI tools (e.g. ChatGPT, MidJourney, Copy.ai, Perplexity.AI) have revolutionised the generation of realistic context-aware content, along with the ways humans interact with AI systems towards retrieving information [2]. Furthermore, the development of domain-specific LLMs based on proprietary knowledge have demonstrated the power of LLMs in carrying out specialised tasks. Specifically, the domain-specific enhancement, training, and customisation of LLMs enables the production of relevant and accurate content for industrial tasks based on proper prompts. Upon integration with XR devices, custom LLMs could facilitate the interaction with the workers based on user-friendly chat interfaces. Nevertheless, the development of domain-specific LLMs towards interactive development of customised content is associated with several challenges: (i) The enhancement of LLMs with knowledge missing from their training datasets through Retrieval Augmented Generation (RAG); (ii) Their fine-tuning towards domain-specific LLMs; (iii) The development of proper prompts for effective interactions via prompt engineering; and (iv) The development of efficient agents and functions for LLMs to effectively respond to such prompts.

The XR2IND project, developed in the scope of the Open Calls of the EU funded XR2Learn project (Horizon Europe Grant Agreement No: 101092851), designs and implements a naturalistic, chat-based, human-centric system for XR-based industrial training applications, notably applications that train workers in the maintenance and repair of industrial equipment. The framework interconnects XR-based industrial training applications to a customised domain-specific GenAI/LLM system, which leverages existing mainstream models (e.g., GPT-4 and LlaMA2). This LLM system is enhanced with knowledge for the industrial equipment and maintenance task at hand based on available information, including instruction manuals and Frequently Asked Questions (FAQ) about the equipment operation and troubleshooting (see Figure 1). The XR2IND system comprise the following main components:

- Domain-Specific Knowledge Models: Domain-specific knowledge in XR2IND is modelled based on embeddings [L1]. Specifically, the ADA model is used to generate text embeddings of documents that describe the industrial task (e.g. texts within training manuals).

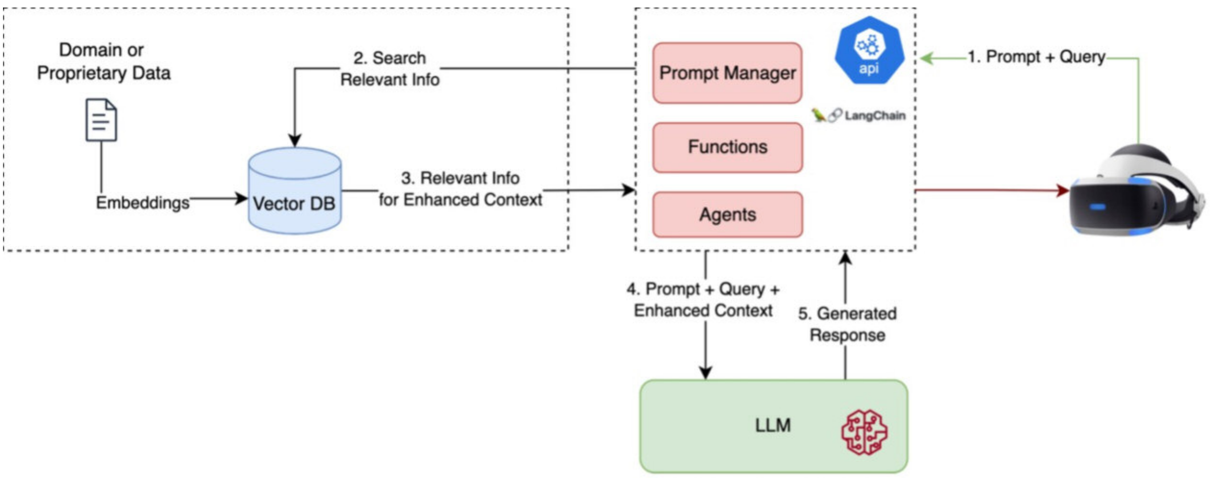

Figure 1: Generative AI enhancing XR applications.

- Vector Database: Documents with text embeddings will be persisted in a Vector Database (such as PineCone, Marqo, and Facebook faiss). The Vector Database will comprise data that are not in the base training set of the mainstream LLMs used (e.g. GPT-4). It will enable searching for instructions, how-to answers, and other user queries.
- LLM Pipelines Engine: A LLM Pipelining engine based on the LangChain framework [L2] will be implemented to support entire workflow from the user's question to the generation of the proper answer by the LLM and its retrieval from the Vector Database. As part of the engine, the project implements a prompt manager that handle the users' prompts, as well as various LLM agents that provide context-aware content generation strategies.
- XR Application for Industrial Training: The training application can be implemented in two setups:
  - VR application, based on Unity that will allow the importing, and holographic 3D visualisation of the use case environment, while allowing the trainee to interact with 3D content.
  - AR application ingesting AI generated feedback to the user based on its interactions with actual environment performing the task at hand.

Overall, the XR2IND system will empower the development of immersive industrial 5.0 training applications leveraging three state-of-the-art domains: (i) GenAI libraries, (ii) XR tools; and (iii) Educational knowledge and content. The project will therefore demonstrate the future personalised XR-based training based on a first of a kind integration between LLMs and XR training applications. The latter will be ergonomic, interactive, user-friendly, and very well aligned with the Industry 5.0 concept.

The work presented in this article has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101092851 (XR2Learn).

Links:
[L1] https://platform.openai.com/docs/guides/embeddings
[L2] https://python.langchain.com/docs/get_started/introduction

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A New Dimension of Learning: Exploring the Impact of XR4HRC on Training Efficacy

by Kübra Yayan (Eskisehir Osmangazi University), Yunus Emre Esen (LTG), Uğur Yayan (Eskisehir Osmangazi University)

Embarking on an innovative journey, the XR4HRC (Excellence in Extended Reality for Human-Robot Collaboration) project within the XR2Learn initiative redefines vocational training in the robotics sector through Extended Reality (XR) technologies. This endeavour aims to elevate workforce competencies, quality assurance, and human-robot synergy to new heights, perfectly aligning with the progressive vision of Industry 5.0.

The XR4HRC project (see concept sketch in Figure 1), part of the XR2Learn initiative, which started on 01.01.2024, seeks to transform vocational training and quality control in the robotics and automation sectors using XR. It aims to improve training effectiveness, minimise cognitive load, and increase workforce efficiency, in line with Industry 5.0's requirements. The project highlights advanced human-machine collaboration through immersive learning experiences.

Key to XR4HRC is the partnership among LTG (a technology development and R&D oriented SME in Turkey), known for AR/VR/XR expertise, IFARLAB-DIH at Eskisehir Osmangazi University (Turkey) with its focus on robotics digital competencies, and BEST (Austria), a leading VET provider in Vienna. These collaborations are essential for embedding XR in vocational training to meet the demands of modern industries.

The initiative represents a significant leap in vocational education, using XR to equip the workforce with critical skills, improve quality control, and promote effective human-robot in-

Figure 1: XR4HRC concept sketch.

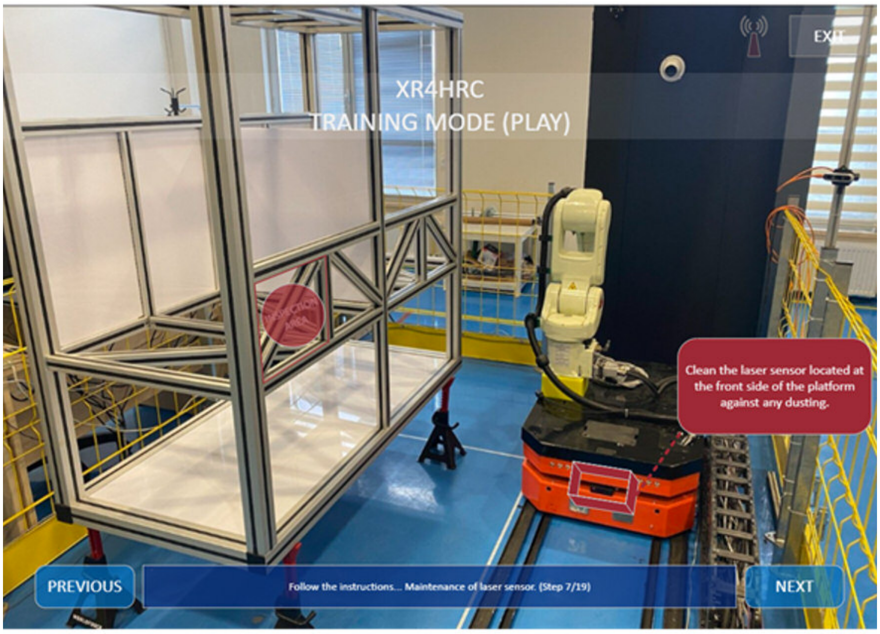

Figure 2: Training mode.

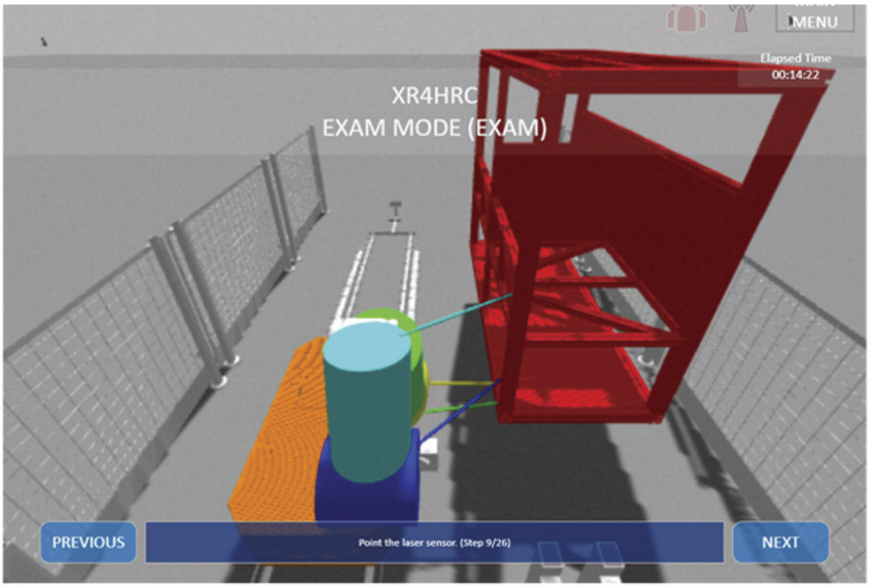

Figure 3: Exam mode.

teractions. It emphasises the role of XR in cutting development costs and enhancing knowledge sharing, aiming to strengthen European XR market competitiveness, especially for SMEs, by offering inclusive and innovative training solutions.

Training Scenarios

The XR4HRC project has developed a comprehensive suite of training scenarios (Figure 2) utilising the immersive potential of XR to advance vocational training in the robotics sector. These scenarios are meticulously designed to not only acquaint trainees with their future work environment but also to ensure their mastery of essential maintenance and safety protocols, critical for secure and efficient operations.

Training Scenarios Overview

Introduction to the Laboratory Environment: This initial scenario introduces trainees to a simulated factory environment, providing a detailed orientation to the workspace, the robot arm, and the robot chassis cabinet, ensuring trainees are well-versed in the operational landscape.

General Maintenance of the Robot Arm: Focusing on the upkeep of the robot arm, this module equips trainees with the necessary knowledge and skills for routine maintenance, emphasising the practical aspects of robotics care to enhance machine longevity and reliability.

Safety Training for Working Safely with the Robot Arm: Dedicated to safety, this scenario integrates critical safety instructions into the XR training, covering essential precautions such as pedestrian-robot path separation, light curtains, and protection against unintended robot movements.

Remote Assessment Enhancement: The project innovates vocational training assessments by introducing remote VR exams, enabling a dynamic and interactive competency evaluation (Figure 3). This approach places both the trainee and evaluator within the same virtual environment, facilitating a real-time, in-depth assessment of the skills and procedures learned during training.

Integrating remote VR exams into the XR4HRC initiative marks a significant leap in vocational training assessment methods, utilising VR technology to make evaluations more efficient, engaging, and safe.

Implementation of the XR System in the XR4HRC Project

Within the XR4HRC project, training sessions employ Augmented Reality (AR) to superimpose crucial information onto physical components in the laboratory, enhancing the learning experience. In contrast, assessments utilise Virtual Reality (VR) to fully immerse trainees in a virtual laboratory setting, allowing for an in-depth evaluation of their skills.

The project integrates the Meta Quest 3 hardware, chosen for its advanced passthrough technology, which merges real and virtual environments using the device's front-mounted camera and sensors [L1]. This fusion of realities is augmented by the ability to interact with virtual objects using the headset's controllers or direct hand movements.

Unity is the primary development platform for the XR4HRC modules, selected for its vast library of assets and the adaptability of C# scripting, crucial for customising virtual components to meet the project's educational goals. The “Interact” plugin within Unity is vital for crafting scenarios, especially for the assessment modules, offering features like kinematic movement simulation and 3D model integration [L2], thus ensuring the virtual laboratory's realism. Developed by the LS-Group in France, this plugin facilitates sophisticated development, making it approachable for users with limited programming expertise.

To prepare for multi-user assessment modules, the project addresses network challenges, particularly synchronisation and latency. The "Netcode" Unity plugin is employed to establish stable communication channels between participants and evaluators, using a server-client model to reduce network inconsistencies, ensuring a smooth and synchronised virtual experience [1], [2].

Discussion
The XR4HRC project, within the XR2Learn initiative, targets the modernisation of VET in alignment with Industry 5.0, utilising XR to enrich training in robotics. It emphasises practical skills, quality control, and human-robot collaboration. While showcasing the potential of XR to enhance learning and operational efficiency, the project also confronts challenges such as remote collaboration and the need for higher Technology Readiness Levels (TRLs) to ensure real-world applicability.

Conclusion
The XR4HRC project endeavours to enhance VET within the robotics sector through XR technologies, focusing on immersive and interactive training experiences. As the project progresses, it seeks to overcome existing challenges and achieve higher TRLs, laying the groundwork for future advancements in XR-based vocational training.

The XR4HRC Project has received funding from the European Union's Horizon Europe research and innovation action programme (grant agreement Nr. 101092851).

Links:
[L1] https://developer.oculus.com/documentation/unity/unity-passthrough/
[L2] https://www.ls-group.fr/interact

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Proximity Machinery through Distributed Augmented Reality: Design for Training the Resilient Operator 5.0

by Alessandro Pollini, Tania Sabatini and Sara Traversari (BSD Design)

In manufacturing, Human-Line Interactions (HLI) are characterised by three aspects: the operator's loss of situational awareness due to the opacity of the systems [1], the complexity and interdependency of all the automation functions, and the machine autonomy that always requires to be clearly communicated. The PROXIMA project solves for these aspects by creating an Augmented Reality (AR) Training Kit that supports and enhances human cognition in the act of learning in HLI-based environments.

With the focus on human cognition in the act of learning, the PROXIMA (AR) Training Kit will seamlessly integrate spatial guidance, machine and equipment training, and hazard identification, through virtual simulations and real-time contextual instructions [2, 3]. A key aspect of the Kit is proximity, both in terms of spatial factors (i.e. user's position with relation to the line and workspace features) and human factors (i.e. the machine is shown differently based on the user's knowledge and necessities).

Human Cognition at Heart
As a general scope, the Kit aims to increase the acquisition of production line management skills; to promote production processes knowledge, and to enhance the capability of breakdowns' remediations. This will also bring the development of personal trust, accountability, and autonomy in high-automation lines.

The Kit reaches the above results by having human cognition at heart. In fact, the Kit is made of three key modules: 3D Visual Storytelling, Training Authoring Tool, and AR Training. The innovation of the Kit lies in the investigation of users' psychological (knowledge, skills, and attitudes towards automation) and cognitive (learning, inspection, awareness, decision-making) dimensions via 3D storytelling; in the way the Authoring Training Tool enable tailoring of the training programmes on trainees' needs; and in the on-field AR training that enables practice sessions immersed in relevant real-life scenarios.

The product is being prototyped with the objective to validate its efficacy in real-life situations and it will be considered successful if the modules effectively contribute to the operator's learning experience.

The Modules
- 3D Visual Storytelling Module: the Kit will present stories describing user control vs. machine automation challenges

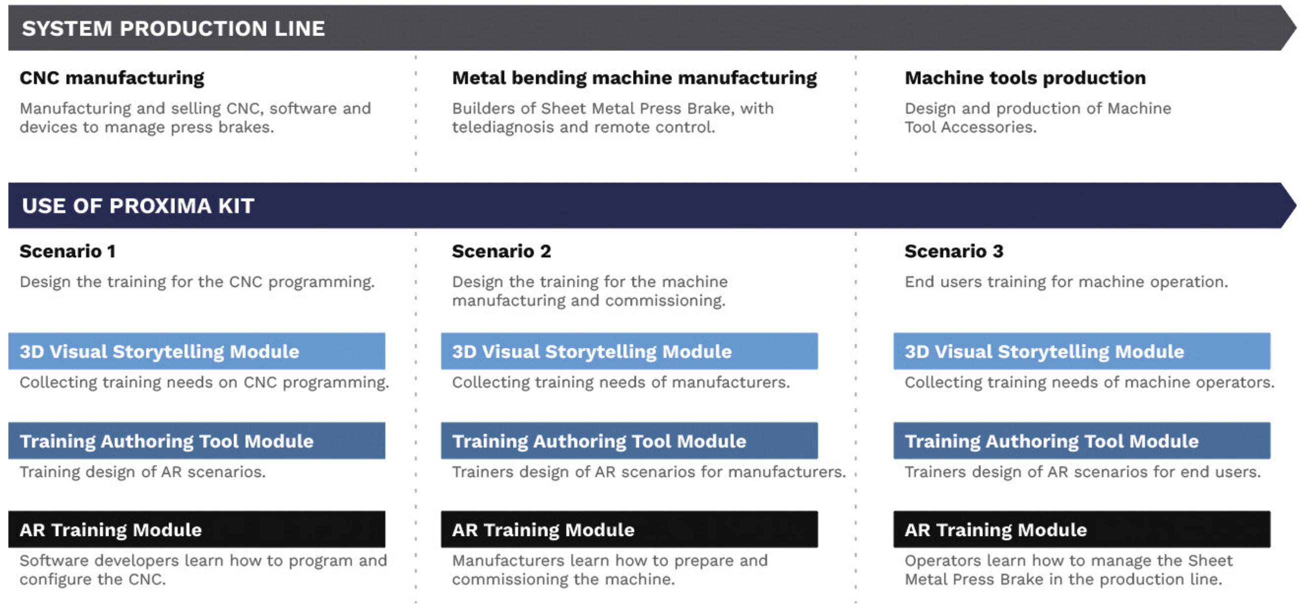

Figure 1: Outline of a case study addressed within the PROXIMA project.

and proposing decision-making dilemmas. This approach aims to stimulate users' reflection about different interaction styles and to collect data about their preferences, prior knowledge of and current attitude toward automation. This module will include three stories typical of HLI environments: automation monitoring; semi-automatic routines and human-machine collaboration; and breakdowns' recovery. Data on operators' trust, expectations, and attitudes will be collected and will inform educational scenarios.

- Training Authoring Tool: the project will develop the AR-specific version of the tool that will support expert users and trainers in building the educational scenarios by: (a) Scanning real physics about the actual production environment following this logical phase: material preparation (e.g. position and physical properties), program (e.g. the product recipe), transformation, fine tuning, product quality; (b) Retrieving documentation and technical specifications; (c) Defining the Scenario Graph with points of interest for critical interactions with industrial machines, and the related natural interaction strategies, including the triggers for the human action, the decision nodes, and the consequences of the action; (d) Producing visual training content to be visualised in AR layers.
- AR Training Module: Through the AR layer, trainees will be provided with simulations and contents as resources to learn automation processes and enable them to manage critical situations. Specifically, in relation to the trainee's spatial position, consistent visual instructions for interacting with smart and automated machines will be provided to the trainees considering their decision-making style and system control preferences (e.g. according to the desired level of automation). These AR contents are enabled by the user's spatial position detection and personalised according to the educational scenarios (i.e. Training Authoring Tool).

With PROXIMA, we aim to offer training experiences in symbiosis with the production line. Thus a stable and reliable framework is needed to structure tailored HLI for each project.

Although one of the goals of this project is to achieve commercialisation of the Kit, we intend to release open-source functional building blocks, giving priority to virtuous exchanges with EU open source community on XR – in line with the European sharing policies on digitalisation. This would allow for both efficient development of the technology and the blossoming of procedures that spread the know-how and encourage the dissemination of the principles of industrial upskilling and reskilling in virtual environments.

PROXIMA is proposed by BSD in partnership with PROTESA and the University of Bologna. It has received funding from the European Union's Horizon Europe research and innovation action programme, via the XR2Learn project (grant agreement Nr. 101092851). The project started in January and will conclude by the end of December 2024.

Links:
[L1] https://kwz.me/hAG
[L2] https://www.bsdesign.eu/PROXIMA-eng

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The XR2Learn Project Approach to Empowering Immersive Learning and Training Leveraging European XR Industry Technologies

by Ioannis Chatzigiannakis (Sapienza University of Rome and CNIT), Silvia Giordano (University of Applied Science of Southern Switzerland - SUPSI), and Theofanis Orphanoudakis Theofanis (Hellenic Open University)

Extended Reality (XR) has become a tangible possibility to revolutionise educational and training scenarios by offering immersive, interactive and personalised experiences. The XR2Learn [L1] project aims to establish a cross-border innovation community for XR in learning, bringing XR technology providers, application designers, education experts, application developers, end-users and decision-makers in direct access to communicate, collaborate and matchmake interests enabling also bottom-up innovation creation.

The proliferation of personal and mobile devices equipped with enhanced processing and networking capabilities has facilitated the realisation of XR across diverse innovative domains. XR is no longer confined to research labs or exclusive to corporate entities, nor does it necessitate substantial investments in specialised software, hardware, or expert teams. Instead, it can be approached as a viable endeavour accessible to a broader audience.

While XR technology holds promise for diverse applications across various sectors, its primary utilisation currently revolves around gaming, entertainment, engineering, and medicine, with tourism and e-commerce following suit. Surprisingly, the educational realm lags significantly behind, despite abundant literature showcasing XR's myriad benefits in this domain: expanding knowledge domains, fostering active learning experiences, enhancing comprehension of complex subjects, mitigating distractions during study sessions, stimulating creativity among students, and enhancing learning efficiency, among others. The increasing demand for lifelong learning and the necessity to upskill/reskill individuals from diverse backgrounds, with varying levels of IT literacy and linguistic diversity, mandates the integration of XR technologies into educational and training frameworks. For instance, the manufacturing industry grapples with the substantial challenge of training its workforce on emerging Industry 4.0 and 5.0 technologies on a global scale.

The XR2Learn project has developed an innovation platform that promotes cross-discipline fertilisation with the aim of reducing the costs of developing XR applications tailored for the education domain (see Figure 1).

At the technical level, the platform incorporates a range of solutions made available for free to the EdTech community ranging from ready-to-explore and experiment-with-beacon applications, to AI-assisted software enablers and \models and low-code tools to reduce the development life-cycle of Intelligent Tutoring Systems (ITS) that enable the adaptation of interactive and virtual experience-based learning activities. The INTERACT tool included in the XR2Learn platform goes beyond basic 3D object manipulation and avatar navigation in virtual environments by addressing aspects such as ergonomics, advanced physics for object and trajectory tracking, and more [1]. The Lego-like approach democratises the virtual simulation, easing to everybody the development of XR applications. A toolchain of innovative components is also included for emotion/affect detection and for automated adaptation of the learning experience to the user needs and emotions, supporting the delivery of applications enriched by affective computing [2]. In doing so, XR2Learn promotes personalised immersive learning experiences that increase the educational solution effectiveness.

At a business level, the platform supports the commercialisation of innovative competitive use-case driven applications by assisting innovators in liaising and collaborating with education experts, which can assist in sound educational scenario definition to ensure market potential. Special emphasis is given to the validation of applications by organising pilots and setting-up campaigns with early adopters, involving trainers

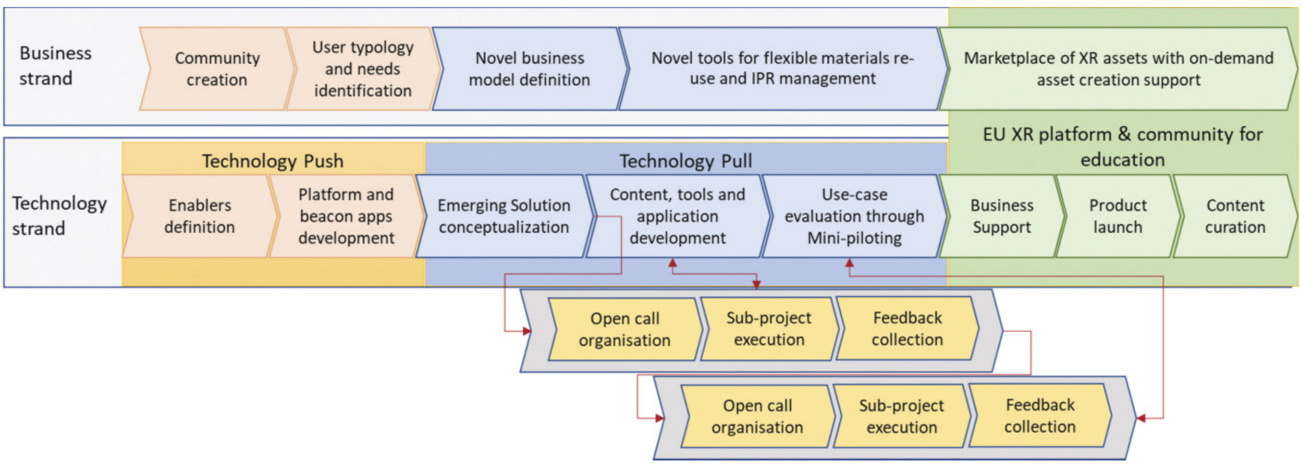

Figure 1: Structure of the XR2Learn project innovation platform.

and training institutions to cooperate with and deliver sound assessments [3]. A tool for flexible IPR management and licensing through NFTs is included to promote easy trading of all types of resources including 3D models, scenes, software modules applications and tools and support innovators and even individual professionals create and share resources, fuelling new business models and the creation of new roles.

The XR2Learn platform extends beyond a catalogue facilitating easy access to solutions and becomes itself a tool towards efficient user/provider on-demand collaboration boosting innovation. XR2Learn focuses on the development of a functional ecosystem with active stakeholder engagement, training and support leveraging innovative business models towards its sustainable future evolution. With the support of the Horizon Europe programme, XR2Learn is organising two open calls to further support digital start-ups, SMEs and industry active in the sector through Financial Support for Third Parties actions allowing them to further advance early prototypes of XR educational solution to a market-ready product, with the overall aim to populate the on-demand education platform.

During 2023 XR2Learn carried out the first open call, providing support for fully developed, tested and ready-to-deploy digital learning solutions/apps using XR technologies. Seven projects have been selected that will go through a fast-paced acceleration programme with focus on the development of content, tools and applications that will be ready for validation [L2].

During 2024 a second open call will be performed aiming to support innovative SMEs in piloting XR-based applications in relevant environments to reach high Technology Readiness Levels (TRL) and Market Readiness Levels (MRL).

Links:
[L1] https://xr2learn.eu
[L2] https://xr2learn.eu/open-call-1/

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Workspace Awareness Cues to Facilitate Mixed-Presence Collaborative Decision-Making on Wall-Sized Displays

by Valérie Maquil, Lou Schwartz and Adrien Coppens (Luxembourg Institute of Science and Technology)

As part of the ReSurf project running at the Luxembourg Institute of Science and Technology, we are working on the next generation of remote collaboration systems using wall-sized displays. The project aims at studying the collaborative behaviour of team members interacting with such displays to solve decision-making problems. Through our observations, we will develop and assess visual indicators for better supporting awareness of collaborators' activities when moving to a mixed-presence scenario involving two distant wall-sized displays.

The 21st century is facing highly complex societal and intellectual challenges that can only be solved when professionals with distinct abilities and resources join their efforts and collaborate. Interactive wall-sized displays provide large benefits for information visualisation and visual data analysis. Besides allowing for a better presentation of large amounts of data, they support collocated collaboration, as multiple users can access and view content at the same time and easily follow each other's actions. Such an "up-to-the-moment understanding of another person's interaction with a shared space" is called workspace awareness [1].

However, in many situations (e.g. sanitary reasons or geographical barriers) face-to-face collaboration is not feasible and needs to be replaced by remote collaboration. Conventional tools used to support such collaboration strongly limit non-verbal awareness information, leading to communication difficulties and additional efforts for staying engaged. This lack of awareness is increasingly relevant in the context of decision-making at interactive wall displays, where collaborators are naturally making use of a large number of body movements and hand gestures like pointing [2].

To better mediate awareness information and facilitate communication, previous work suggests adding additional visual cues into the common workspace or the live video stream. While such visual cues have been proposed for smaller workspaces like tabletops, they haven't been investigated in the context of remote collaboration across two or more wall displays, which is the reason behind the ReSurf project [L1], supported by the FNR.

To be able to study, enhance and evaluate such cues in our context, we developed a decision-making scenario (snapshot shown in Figure 1) involving different types of data on a wall-sized display. This scenario involves four participants, each having a distinct role, collaboratively solving a stock management problem during a crisis. The problem is divided into four subtasks: i) estimating the stock needs, ii) selecting the type of equipment for which fixing the shortage is the most urgent problem, iii) selecting an offer from different suppliers that may fulfil that need, and iv) selecting a delivery method. For each stage, participants are provided with different types of data that they need to manipulate, in order to find the appropriate solution. This involves slider values, graph visualisations, tables, maps, but also news articles. We further impose constraints on them through private information that participants receive based on their assigned role (e.g. "as the head of intensive care unit, I need the missing item delivered within eight days").

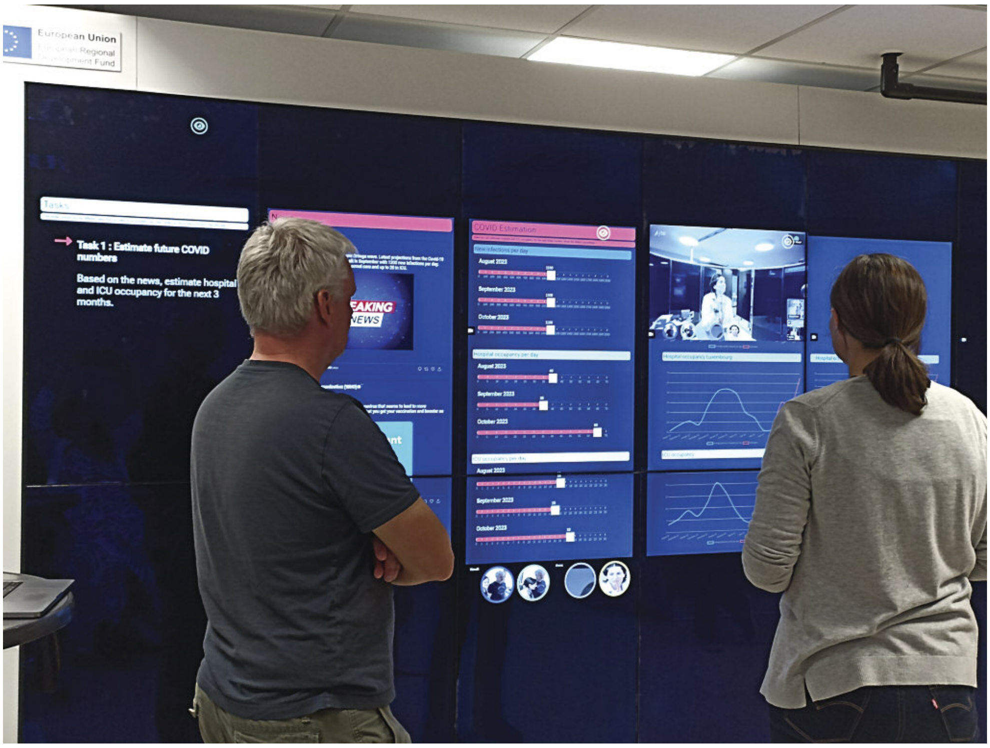

Figure 1: A snapshot of the scenario developed as part of the ReSurf project to study and improve collaborative decision-making using wall-sized displays.

Our first course of action was to run a collocated user study where participants would go through that scenario while interacting from the same room, using the same wall-sized display. This allowed us to analyse their behaviour and identify gestures they naturally and frequently relied on.

We then studied the main issues observed during remote collaboration via a simple (baseline) setup involving only an audio-video link between the two sites, similar to what can nowadays be expected from videoconferencing systems. We organised a focus group where participants went through the decision-making scenario with the aforementioned baseline setup so that they could identify issues resulting from the sole reliance on the audio-video link. Participants could then discuss the issues they noticed and envision solutions that could serve as cues to solve the encountered issues.

We organised their ideas of awareness cues into three categories: environmental, action, and attention cues:
- Environmental awareness cues relate to all elements that can give information about the environment of the distant group, such as the configuration of their wall-sized display and which participants are present in the distant space.
- Action awareness cues concern the information that explains an action, such as the nature of the action, the artefacts it affects, but also who perpetuated it and from/to which location.
- Attention awareness cues give information about the attention of the participants, i.e. where they are looking.

The next step in the project will be to design, implement, and evaluate some of these workspace awareness cues. We will indeed run further user studies with different groups to understand their usage of such cues and whether/how they are beneficial to their collaboration (e.g. in terms of correctness, efficiency, or workload).

This innovative project will ultimately generate empirical knowledge on the optimal design of awareness support in remotely connected wall-sized displays. Moreover, it will contribute to the next generation of remote decision-making tools, where people can collaborate smoothly, and enjoy an experience that is as close as possible to a collocated situation, appropriately balancing between displaying more information and avoiding distractions.

Links:
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XR5.0: Human-Centric AI-Enabled Extended Reality Applications for the Industry 5.0 Era

by John Soldatos (INNOV-ACTS Limited), Georgios Makridis (University of Piraeus Research Center) and Fotis Liarokapis (CYENS Centre of Excellence)

Extended reality (XR) is a term that covers all real and virtual environments, enabling human-machine interactions through computer-generated content. It includes virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies [1]. State-of-the-art XR applications for manufacturing are built based on a "one-size-fits-all" philosophy that does not consider the characteristics of individual workers. Hence, they fall short when it comes to supporting the emerging wave of Industry 5.0 (I5.0) applications that are destined to be human-centric and emphasise trustworthy human-machine collaboration. I5.0 requires XR visualisations that consider the characteristics, skills, and context of the manufacturing worker [2], along with the peculiarities of their interactions with machinery, automation devices, and cyber physical production systems.

In this context, the newly started XR5.0 Horizon Europe Project will build, demonstrate, and validate a novel person-centric and AI-based XR paradigm that will be tailored to the requirements and nature of I5.0 applications. The project will specify blueprints for using XR in I5.0 applications with emphasis on the development of innovative "XR-made-in-Europe" technology that blends with human-centric manufacturing technologies and adheres to European values (e.g. trustworthiness, security/privacy-by-design, transparency) as reflected in relevant EU regulations and policies.

Extended Reality Driven by Trusted Artificial Intelligence and Human-Centred Digital Twins

The XR5.0 applications will consider the characteristics and context of the worker based on the integration of human-centred digital twins (DTs) that comprise the "digital image" of the worker. At the same time, XR5.0 will design and implement a unique blending of XR technology and advanced AI paradigms, including AI technologies that foster the interplay between humans and AI such as explainable AI (XAI), Active Learning (AL) [3], Generative AI (GenAI), and Neuro-symbolic AI. The XR5.0 technologies will be coupled with a cloud-based XR training platform for Operator5.0 applications, which will enable ergonomic and personalised training of industrial workers on widely used manufacturing processes.

The main results to be produced by the project are illustrated in Figure 1 and include:

- XR5.0-ReferenceModel: The project will build a reference model for "XR-made-in-Europe" technology that supports I5.0 applications in-line with European values.
- XR5.0-DigitalTwin: XR5.0 will provide a platform for the development of cognitive, human-centred digital twins that will be able to construct the worker's digital image in a credible way. Such digital images will be accordingly used to personalise the content, the flow, the aesthetics, the locality, and the geometry of XR5.0 applications.
- XR5.0-AI: XR5.0 will build technology that blends XR into advanced, human-centric AI paradigms that are commonly deployed and used in I5.0 applications, such as GenAI, XAI, AL, and Neuro-symbolic AI. This blending will enable a variety of AI-enabled functionalities from the visualisation of AI-generated insights to AI-based interactions with cyber-representations of manufacturing tasks.
- XR5.0-AugmentedIntelligence: XR5.0 will enable new forms of multi-modal augmented intelligence based on the visualisation of AI outcomes (e.g. insights, recommendations, AI explanations) in various production scenarios. XR5.0-AugnentedIntelligence will be integrated within XR solutions of the partners to enable generation of innovative virtual worlds and construction of realistic, yet simulated environments (i.e. simulated reality).
- XR5.0-Training: XR5.0 will build its own cloud-based human-centric Operator5.0 training platform that will include XR content for common I5.0 UCs). The platform will be integrated with other XR platforms of the European XR ecosystem.
- XR5.0-Apps: The XR5.0 paradigm will empower the development of six novel pilot applications spanning the areas of AI-based product design, remote and intelligent maintenance of assets, workers' training, support in product assembly, as well as guidance and instructions for troubleshooting. These applications will be deployed and demonstrated in realistic manufacturing environments.
- XR5.0-Ecosystem: The project will build its own community of XR stakeholders including researchers, XR vendors and providers/integrators of I5.0 enabled XR solutions. The development of this community will boost the sustainability and wider use of the project's results.

XR5.0 will enable novel applications such as the following user journeys (UJ):

- UJ #1 (Personalised, Multi-Modal, AI-Enhanced Workers' Training): A manufacturing worker needs to learn a new process for assembling a complex product. With the help of the XR5.0 training platform, they are trained in a highly customised, multi-modal environment that blends physical and virtual aspects. The environment imitates the manufacturing process while considering the worker's context (e.g. physical characteristics, skills, and emotional status). Moreover, the environment integrates AI features, such as explanations for parts of the process and real-time feedback on the user's activities in the applications. This enables workers to improve their learning experience and satisfaction while at the same time minimising the learning curve for the assembly process.
- UJ #2 (AI-based Sustainable-by-Design Products/Production): A manufacturing product manager wants to optimise a product for sustainability based on a Sustainable-by-Design (SbD) approach, which is suggested in Europe's Circular Economy Action Plan [L1]. To contribute to SbD, XR5.0 enables the manager to visualise numerous product options in a Metaverse-like environment. Using XR5.0 technologies, the manager can visualise hundreds of production configurations to audit them against their sustainability features and CO_2 footprint, but also evaluate their appearance.

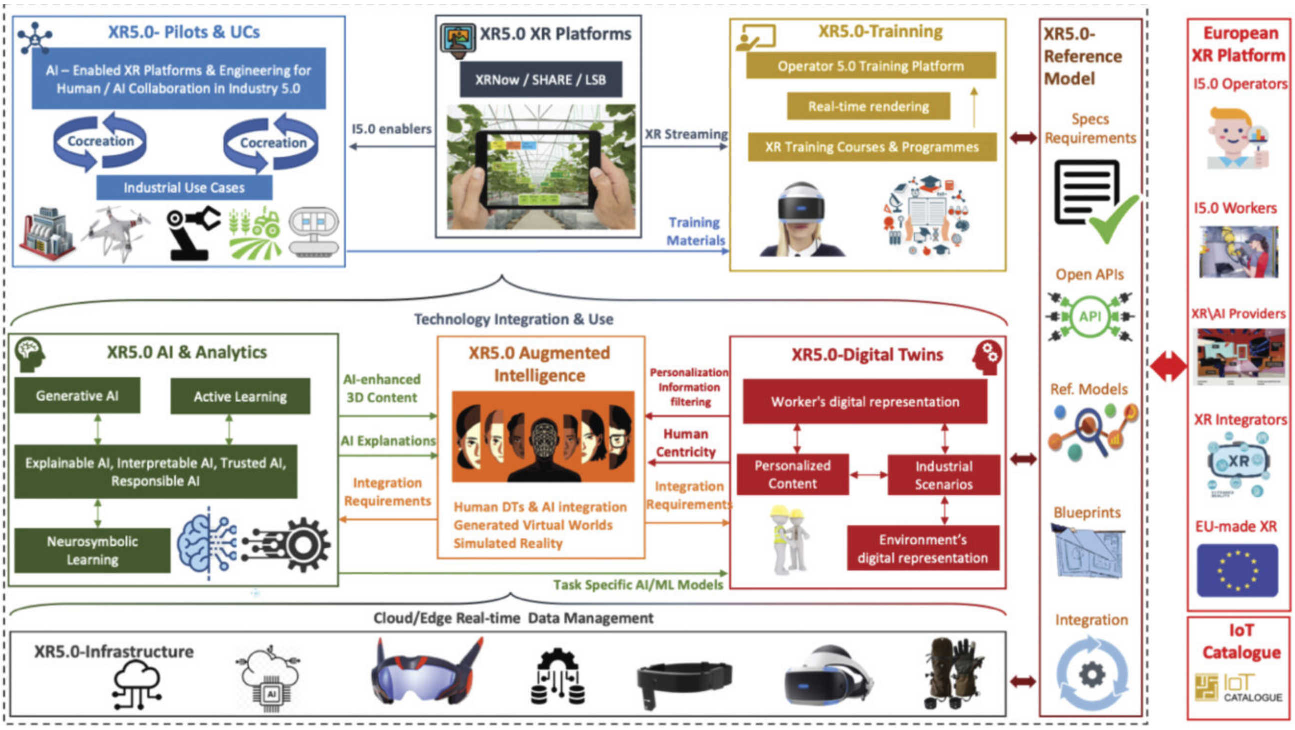

Figure 1: High-level overview of the architecture and enablers of the XR5.0 project applications.

XR5.0 can also visualise explanations, to enable the manager to analyse "what-if" scenarios and improve their decision making. This results in increased productivity for the workers, while improving sustainability.

- UJ #3 (Effective Mass Customisation based on AI and XR): This scenario involves a product designer that needs to create a customised product for a customer, i.e. based on a Made-to-Order (MTO) approach. XR5.0 enables the designer to use a GenAI model for producing multiple design options. The XR environment provides real-time feedback, allowing the designer to make changes on the fly and improve the final product's quality.
- UJ #4 (Personalised Remote Instructions and Support in Maintenance Processes): A maintenance manager needs to service a complex piece of machinery, which requires the expertise of the machine builder. XR5.0 obviates the need for costly travels to the remote site, as the machining expert can provide personalised remote guidance to an on-site technician. The remote guidance is visualised in an XR environment based on instructions tailored to the skills of the technician. XR5.0's AI and personalisation features enrich the standard instructions with personalised information, alerts, assistance, and contextual explanations. These features enable the technician to complete service and repair processes quickly, safely, and efficiently.

The work presented in this article has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101135209 (XR5.0).

Links:
[L1] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

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Putting the Human First and Second: Challenges of Building a Human-Centred Industrial Metaverse

by Katharina Hölzle (Fraunhofer Institute for Industrial Engineering IAO and University of Stuttgart) and Matthias Aust and Steffen Braun (Fraunhofer Institute for Industrial Engineering IAO)

The industrial metaverse offers the potential to fundamentally disrupt our understanding of technology-assisted collaboration and therefore requires an interdisciplinary approach across the domains of Extended Reality (XR), AI, ergonomics, and innovation management. Consequently, we develop a unique hard- and software infrastructure for co-located and multi-modal communication-, meeting-, and planning-lab use cases. This will enable different industries to take the first steps into a human-centred metaverse for future product development, engineering, service development, and co-innovation.

The significance of virtual or, better, extended environments is nothing new. Previous contributions in this field have addressed physical aftereffects and the sense of presence in virtual environments decades ago and formulated a strategic research and development agenda [1]. Nevertheless, the technological progress over the past 30 months since the announcement of 'the' metaverse by one specific company has created a new hype cycle with a significant expected impact on several industries. Metaverse markets are predicted to reach volumes of up to USD 394 billion by 2025 and USD 5 trillion by 2030 [2] [L1]. A scientific stakeholder analysis in 2023 has identified over 700 companies and institutions working on metaverse-relevant technologies and applications on the state level of Baden-Württemberg alone (ibid.). Consequently, companies and researchers alike are trying out various architectures, applications, and use cases for the industrial metaverse.

Based on these premises, an interdisciplinary research team at Fraunhofer IAO has started the applied research project INSTANCE (Immersive iNduSTriAl iNnovation eCosystEms) to develop, prototype and transfer an XR infrastructure within and between different locations of the research institute, focusing on collaboration in new product development and engineering. The key research question is how metaverse technologies will transform these fields and, at the same time, open up new fields for future industries.

Motivation for Immersive Industrial Innovation Ecosystems (INSTANCE)

The concept of the industrial metaverse continues to evolve rapidly, as numerous industry applications are emerging and the scientific discourse is just starting to gain momentum (e.g. [3]). We view the industrial metaverse as a vision of an immersive environment at the interface between reality and virtuality, in which human and artificial avatars collaborate virtually, economically, socially, and creatively [2] [L1]. It can be characterised by persistence, ubiquity, scalability (cf. cross-instance identity, connectivity, infrastructure), immersion (cf. XR, sensor technology), interoperability (cf. open standards, decentralisation), and value-add (cf. digital innovations). Its key features involve the seamless integration of digital twins as well as AI solutions, driving innovations across the value chain – e.g. in open foresight, new product development, training and development, or predictive maintenance. To this end, substantial challenges must be resolved, such as ensuring its users' digital competencies and providing an adequate infrastructure based on open standards to allow for interoperability.

We argue that the innovation-driven, knowledge-intensive work in an industrial metaverse is best captured by the notion of an innovation ecosystem – that is, the industrial metaverse will be shaped by complementary contributions of various actors toward collaborative value creation. Notably, this perspective transcends geographical and organisational boundaries, differentiating it from today's mostly isolated digital twins or XR solutions. Considering this, the industrial metaverse offers the potential to transform our understanding and the implementation of the human-machine interface in industrial contexts and, consequently, requires an interdisciplinary approach across the domains of XR, AI, ergonomics, and innovation management.

Research Approach and Methodology

INSTANCE brings together expertise and experience from various fields, including human factors engineering, design, innovation research, generative AI, immersive technologies

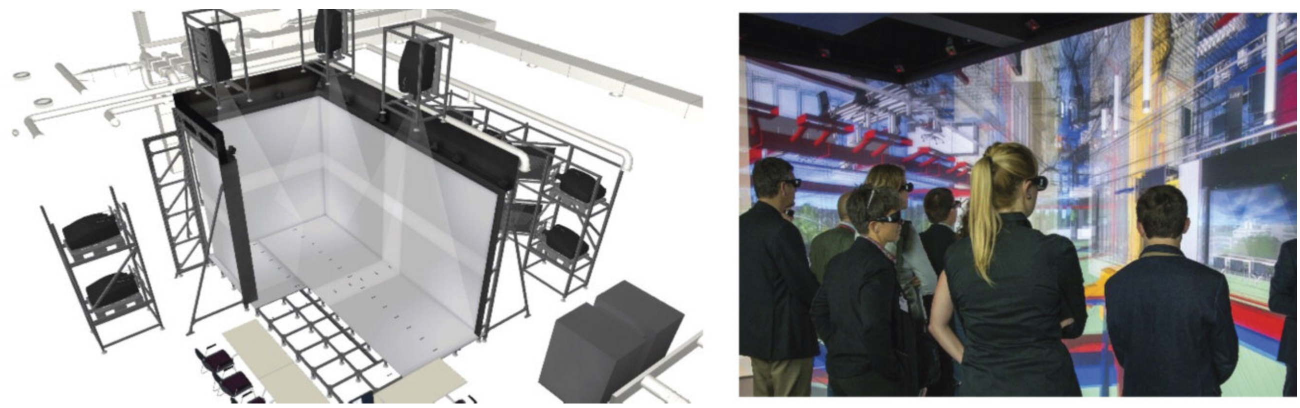

Figure 1: The CAVE in Fraunhofer IAO's Immersive Participation Lab [L2] will be updated with new projection- and computing hardware and become one of the main INSTANCE portals.

(such as virtual and augmented reality), urban systems research, and corporate culture and transformation research. We approach our research questions through two parallel streams, each focusing on a different aspect: (i) infrastructure and (ii) application, both with the goal of building prototypes.

In the infrastructure stream (i), we analyse hardware and software components. We conduct market analyses to determine if available metaverse software platforms meet our requirements, including the use of open standards, open source, independence from proprietary systems, decentralised network architecture, data security, and the ability to host our own prototypical system. The required hardware infrastructure extends beyond networking infrastructure. Leveraging decades of experience in large Virtual Reality Systems, such as Powerwalls and CAVEs, we will extend existing infrastructure by updating systems, and equipping more labs with Powerwalls and Head Mounted Displays. The envisioned result is a network of "connected XR portals" into an innovation ecosystem distributed across multiple locations across Germany (see Figure 1).

The application stream (ii) intersects with the infrastructure stream through the user-interface hardware. The portals in different locations are operated by different research teams, each with their own research focus. Multiple metaverse applications will be conceptualised and implemented as prototypes. Trainings will be offered, and experiments run to learn in-depth how humans interact in and with metaverse technologies, which skills are needed, how organisational structure and processes are impacted, and what new forms of technology-assisted collaboration will look like. Examples include AI-assisted innovation workshops, experiments enhancing creativity through virtual surroundings, and facilitation of advanced systems engineering. These applications range from sandbox systems for researchers to customer-ready virtual engineering systems.

Outlook on Future Research Towards Neuroscience-Based Evaluation

Our general approach involves progressing from experimentation to scientific evaluation and optimisation. Each step will provide valuable experiences and best practices that customers and research partners will be able to benefit from.

Based on the experiences enabled by pilot applications using the INSTANCE infrastructure, it is planned to focus on scientific evaluation of the quality of XR sessions using both quantitative and qualitative methods. For quantitative metrics, we will mainly use data-based methodologies of our brain-computer-interaction scientists; for qualitative metrics, we will use AI-based conversation transcription and evaluation. Based on established user-experience methods, we will then be able to measure and systematise different XR configurations and help to find best-fitting solutions for specific use cases.

Applied research at Fraunhofer IAO aims to translate scientific discoveries into real-world applications to benefit industry and society. INSTANCE will be a sandbox for many industries towards exploiting metaverse potentials with humans first and second.

Link:
[L1] https://kwz.me/hAI

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Reaching Behind the Glass: Fashion Exhibition and Social Virtual Reality

by Karolina Wylężek, Irene Viola and Pablo Cesar (CWI)

Museums’ objects, often having outlived their owners, continue telling the story of the past and educate us about the history. Sadly, they also do not last forever. Passing time gradually makes them more and more fragile, finally rendering them too vulnerable to be shown on a display ever again. Luckily, new technologies come with solutions to keep relics of history accessible even after their physical “lifetime” ends. At CWI [L1], we decided to develop a social VR system that would allow us to experience and interact with objects long after their time has passed.

Reasons for digitalisation of museums and their exhibits are countless, from providing better accessibility for disabled people and individuals in distant locations, through improving the attractiveness of the exhibitions and allowing for information personalisation, to maintaining the image of objects after they are too old and delicate to be displayed. For some exhibits, like fashion artefacts, there is also another dimension to be considered – the role they play in people’s lives. Clothes – objects being kept closest to our bodies, make us feel a natural desire to interact with them [1]. That is where, together with curators from Centraal Museum in Utrecht [L2], European Fashion Heritage Association [L3] and the Netherlands Institute for Sound and Vision (NISV) [L4], we came up with the idea of creating the exhibition inside a virtual environment – it would allow broader access to museums and the relics of history, and stretch the interaction boundaries that exist in physical museums.

Figure 1: First prototype of the system including some of the selected for the exhibition garments.

The question that came then was how to do it right. According to the literature, for most visitors, the social aspect is the most important part of the museum visit [2]. People need to have a companion with whom they can share their opinions and search for validation of their reactions. It is also an occasion to strengthen the bonds with family members, friends or a partner. Taking into account how important the social factor for museum visitors is, we decided that the exhibition should be created within a social VR environment. Social VR would allow people to visit a museum together, even while being in distinct locations, and interact with each other almost as they would in the physical world.

After deciding on the technology, there were still many questions to be addressed, like how to present the exhibits in an interesting way, how to make the experience attractive, taking into account differences between visitors and their areas of interest, or how to present information to be engaging. To answer those questions and discuss other potential challenges, we organised a focus group with museum curators, most of whom are members of 5Dculture [L5] – a project that the virtual exhibition is part of. The focus group helped us define five essential concepts: context, emotion (manifested by the concepts of control, connection, familiarity and enjoyment), learning, user experience, and vulnerability. Interestingly, they all connect with each other, creating a coherent whole. Improved learning outcomes appear as a result of a well-designed experience and introduction of familiarity. Context plays its role in achieving educational goals as well. Going further, the connection between exhibits or performances, which were defined as part of user experience, can be a tool in building the context. On the other hand, context is a very important element in achieving immersion, which strongly influences the experience. Finally, vulnerability was concluded to be an important topic of the exhibition, being able to evoke emotions and giving opportunities to build a context.

Following the findings of the focus group, the design process of the system has begun. Pieces too vulnerable to be displayed in a traditional way were selected by curators of the Centraal Museum in Utrecht [L2] and 3D-scanned. They will be placed in the system, where visitors will be able to see and interact with them (for example by rotating them) (Figure 1). To enable free interaction between the visitors, we decided to use VR2Gather – a system providing real-time 3D image capturing developed by our team [3]. It allows users to "teleport" into VR – thanks to point cloud technology, the visitors look in the virtual environment exactly the same as in the physical world. As the users' whole bodies are reflected in the digital space, they can not only talk but also use nonverbal communication means, like gestures or body posture. This is expected to also have a positive influence on immersion and presence – aspects very important for a good user experience. An important decision to be made is how to approach context. Since it appears to have a big impact on many aspects of the system, we decided to test three different variants of the exhibition, each building a different context around the exhibits by adjusting how the museum space and users' clothing look:

1. Variant 1: Museum space neutral, users wearing their original clothes.
2. Variant 2: Museum space styled as an elegant museum, users wearing their original clothes.
3. Variant 3: Museum space styled as 19th-century interior (times of the exhibits), users wearing 19th-century clothes.

In the last scenario, body-tracking will be used to make users appear as if they are wearing historical garments. The prototype including these three variants of context will be tested, and based on the results we will continue the project with the one having the best influence on the user experience. During the first round of testing, we also aim to find ways of improving interactions and the way the story [L6] of the exhibits is presented.

The final version of the exhibition will be presented in June 2024 in NISV [L4]. The museum visitors will take part in the experience together with their companions, and we will be able to collect the data to assess the systems' influence on visitors' museum experience and learning outcomes.

Links:
[L1] https://www.dis.cwi.nl/
[L2] https://www.centraalmuseum.nl/en?set_language=en
[L3] https://fashionheritage.eu/
[L4] https://www.beeldengeluid.nl/en
[L5] https://5dculture.eu/
[L6] https://www.dylaneno.com/

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TRANSMIXR: Enabling the Future of Media Experiences through Social XR

by Silvia Rossi, Irene Viola (CWI) and Pablo Cesar (CWI and TU Delft)

Thanks to the recent advance of Extended Reality (XR) and Artificial Intelligence (AI) technologies, researchers in the European TRANSMIXR project are working on the future of media experiences by advancing the state-of-the-art in media production, delivery and consumption. In this context, we developed an open-source system for volumetric real-time interaction for social VR, collected user requirements and proposed new metrics to evaluate the quality and user experience in XR environments.

Our experience with media content has changed over the past few years: from being a merely passive activity, it is now becoming more immersive and interactive. While keeping a pivotal role in our information and entertainment world, traditional media content, which is typically two-dimensional and non-interactive, is facing new challenges: our society seeks more realism, social connectivity, and interactive engagements in their virtual experiences. This shift has seen XR technologies emerging as a new medium that allows users to share immersive experiences with others, making the vision of a feeling of "being remotely together" a realistic goal. At the same time, the development of mature AI tools has unlocked unique opportunities across several sectors. Without a doubt, the synergetic use of these emerging technologies will be crucial in writing the future of media experiences. This is indeed the vision of a new European project, TRANSMIXR, which aims at revolutionising the cultural and creative sector.

TRANSMIXR wants to step forward in the entire production chain of future immersive media experiences, from creation to consumption. Developing a range of AI and XR solutions, the project aims at reshaping digital co-creation, interaction and engagement experiences, focusing on three main domains of the cultural and creative sector, such as news media and broadcasting, performing arts, and cultural heritage. The vision is to introduce a novel XR Creation Environment to foster cross-investigations and facilitate remote collaboration between media and content creators. In the performing arts sector and cultural heritage, the idea is to design XR Media Experience Environments for the delivery and consumption of highly dynamic and socially immersive media experiences across multiple platforms to audiences who may not have regular access to arts and culture. For example, Figure 1 shows on the left side the physical set up of two participants experiencing a museum in social VR while on the right side their virtual experience while interacting with heritage artefacts [L2].

In the context of TRANSMIXR project, the focus of the Distributed and Interactive Systems group at CWI [L3] lays in three main research directions: (i) to gather user requirements and understand current production workflow; (ii) to improve the technology that allows the creation of immersive and interactive experiences; and (iii) to define a range of metrics to evaluate the quality and user experience.

Gathering User Requirements

While the production workflow for traditional media is well understood by both clients and producers, creating XR experiences presents an additional challenge in how to manage communication and expectations between technology enablers, designers, and final consumers. A series of user-centred workshops have been conducted in order to explore what possibilities and opportunities lie in enabling social XR in various stages of the production workflow and thus, provide a clear set of tools that will be useful for the production of next-generation immersive applications. We found pain points in each of the stages for XR production: pre-production, production, post-production, and post-release. In particular, our workshops highlighted the need for social XR tools to improve communication in each step of the workflow, for example to show initial sketches and final prototypes to the clients, making communication easier and more effective.

Improving XR Technology

To enable efficient communication tools in social XR and make the immersive experience more realistic, it is essential to guarantee immersion, presence and interactivity to any final users. Due to technological limitations, many solutions still offer immersive experiences using synthetic avatars to represent users, which decrease the sense of presence with respect to photorealistic representation. Therefore, our research efforts have been put into developing VR2Gather platform, an open-source system for volumetric real-time communication and interaction that can also enable social VR experiences [1]. This platform is

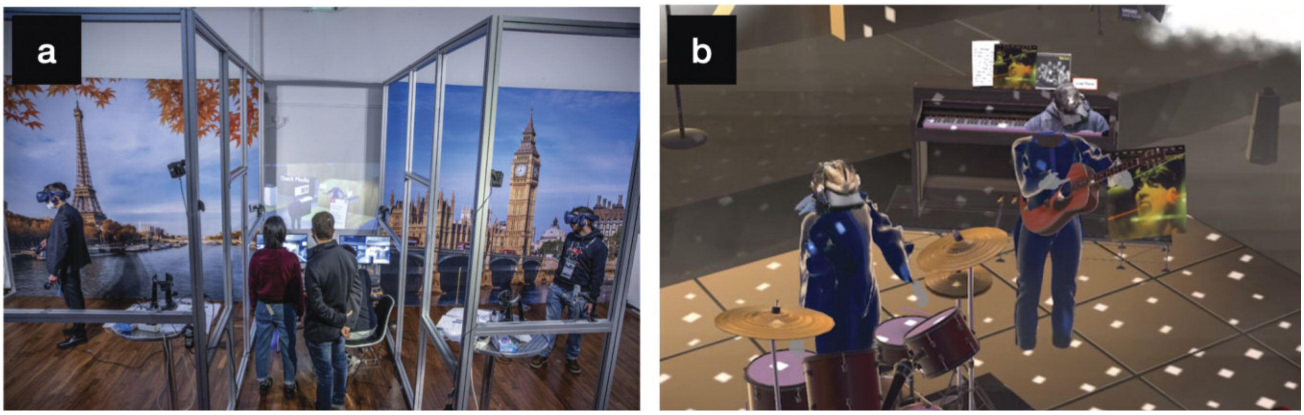

Figure 1: a) Physical setup of two participants (left and right) experiencing a museum in social VR with two operators (middle); b) Virtual experience of the two participants within the virtual museum.

composed of different modules to capture, encode, transmit and render volumetric content in real time and can be adapted to different 3D capturing devices and camera configurations, network protocols and rendering environments. Thus, our system represents an initial solution that can be used for enhanced communication and collaboration between professionals of the creative and cultural sector.

Developing Metrics for Quality and User Experience in XR

New XR experiences need metrics that are able to adequately capture how users perceive this new medium, and how they navigate and interact. For example, understanding how users behave in virtual spaces can help us improve their experience and tailor our technology around their needs. In this context, we focused on enabling the detection of correlations and similarities among users while experiencing social VR by investigating new methodologies for better modelling user behaviour and novel tools of clustering [2]. Similarly, understanding how users perceive emerging 3D content such as point cloud, and what features of the content are more salient in terms of visual attention, is fundamental to optimise compression and delivery without compromising the user experience. Thus, we also filled this gap by proposing new objective quality assessment metrics and a novel publicly available dataset of eye-gaze data acquired in VR environment [3].

The TRANSMIXR project is within the Horizon Europe framework, the European Union's research and innovation programme for the 2021–2027 period [L1]. The TRANSMIXR consortium includes 19 organisations (seven universities and research centres, seven media practitioners and five industry partners) from 12 European countries holding advanced and complementary expertise and skillsets in European research, media and innovation programmes, as well as in-depth knowledge of AI and XR and their application to the media sector.

The work presented in this article was in part supported through the European Commission Horizon Europe program under grant 101070109 TRANSMIXR [L1].

Links:
[L1] https://transmixr.eu
[L2] https://kwz.me/hAM
[L3] https://www.dis.cwi.nl/

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Collaboration in a Virtual Reality Artwork: Co-creation and Relaxation beyond Technology

by Julien Lomet (Univ Paris 8, Univ Rennes 2, IRISA), Ronan Gaugne (Univ Rennes, Inria, CNRS, IRISA) and Valérie Gouranton (Univ Rennes, INSA Rennes, Inria, CNRS, IRISA)

Collaborative virtual spaces allow to establish rich relations between involved actors in an artistic perspective. Our work contributes to the design and study of artistic collaborative virtual environments through the presentation of immersive and interactive digital artwork installation, named "Creative Harmony". In this project, we explore different levels of collaborations proposed by the "Creative Harmony" environment, and we question the experience and interactivity of several actors immersed in this environment, through different technological implementations.

The collaborative artwork "Creative Harmony" ("CH") [1][L1] was designed within a multidisciplinary team of artists, researchers and computer scientists from different laboratories. The "CH" experience is based on a live performance that involves a dancer and a musician who are performing in front of an immersed public, and collaborative spectators who are remotely engaged to the experience through full-body movements (Figure 1). The performance is structured around three phases, one introductive meditative phase to be immersed in the universe of "CH", one active phase of co-creation of a shared landscape whose aesthetic is inspired by the German Romantism painting from 19th century (Figure 2), and a last phase of contemplation of the co-created landscape. In order to foster co-presence, each participant of the experience is associated to an avatar that aims to represent both its body and movements, but in an artistic semi-humanoid appearance. The music is an original composition designed to develop a peaceful and meditative ambiance to the universe of "CH".

One originality of the "CH" experience is the exploration of the relaxation of the spectators. We propose to explore this complex state of emotion through the analysis of the "CH" experience. A first user study was conducted to measure the impact on mood resulting from immersion and interactivity, taking into account the collaboration, the curiosity of creation, the involvement of the spectator in the interactive process and the contemplation of the resulting virtual environment. We evaluated the impact of the artistic virtual experience on users' emotional state before and after their performance in virtual reality. We proposed a method based on a cognitive approach to evaluate this impact, with a standard tool widely used in psychological studies, the BMIS scale. The study of these results highlighted a significant impact on the emotional state of the participants with increase of positive mood indicators and decrease of negative ones, with the highest evolution for tiredness, nervousness, calmness and happiness [2].

The “CH” experience was exhibited in several artistic and scientific events with adapted technological environments. The underlying VR application was developed in order to ease its deployment in various configurations. The first public exhibition was performed at the international festivals Ars Electronica festival in Linz in 2020 (Figure 3), with a remote collaboration between the Ars Electronica Deep Space facility [L2] and the Immersia research platform [L3], in Rennes, France. For this exhibition, the dancers and the musician were performing in Rennes, in front of a passive audience equipped with stereoscopic shuttles to visualise the 3D content displayed in Immersia. The remote audience in Ars Electronica was immersed in the virtual environment in the Deep Space, interacting with feet positions in the space tracked at ground level with a lidar system. The co-created content was synchronised in real-time between the two sites using a network library in Unity.

In a second exhibition, for a music and science public event, the performance part was the same than in the Ars Electronica while remote interactive participants were connected using HMDs in a remote building of the same city. The users connected with HTC Vive HMDs were interacting through hand movements, tracked via controllers’ positions. This particular configuration was the one used for the user study in [2]. The “CH” experience was also presented in the international Digital Arts and Electronic Music festival LEV in Spain, in 2021 and international Digital Arts festival Recto VRso in France in 2022 (Figure 4). In both cases, we used the same configuration, with two spectators collaborating in the virtual environment connected with Oculus Quest 2. In this configuration, no live performance was associated to the experience. One of the two users was playing the role of the dancer, while the other was playing the former role of connected and interacting spectator. Other public exhibitions of the artistic creation “CH” in various public events implemented either the Immersia-HMDs or HMD-HMD version of the environment, using the same core Unity application.

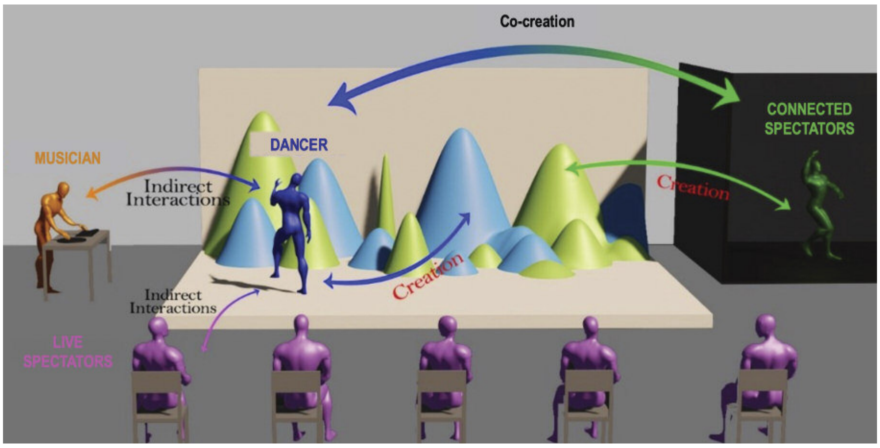

Figure 1: Overview of the “Creative Harmony” principle.


Figure 2: The co-creation scene in the “Creative Harmony” experience.

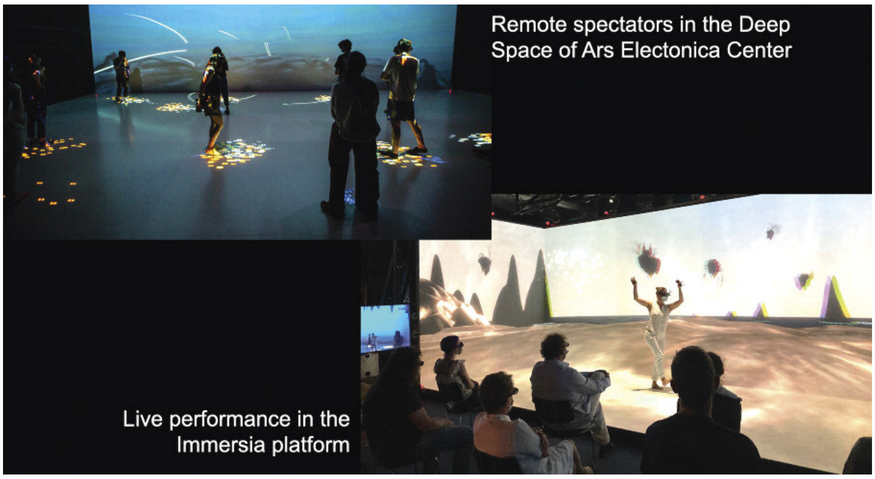

Figure 3: The distant exhibition of “Creative Harmony” between Ars Electronica Center and the Immersia platform.


Figure 4: “Creative Harmony” for two spectators in the Recto VRso festival.

Current research and developments of the "CH" environment are considering and investigating three main directions:

1. New modalities to foster the collaborative engagement. The user study presented in [2] showed a lack of understanding of the co-creation part of the experience. We have integrated new physiological modalities to interact and collaborate in order to enhance co-creation comprehension and engagement. We have also rebalanced the sense of creative freedom for both roles. A user study is currently conducted to assess this aspect.
2. New applications of the experience. Beyond the artistic creation, we want to explore the possibility to benefit from both the relaxing effect and the full-body engagement, particularly through breath interaction and interactive collaboration design. The impact on the well-being of the users is under investigation within a new multi-disciplinary research project.
3. New technological configurations. We investigate in particular a Cave-to-Cave version in order to explore distant collaborative artistic creation and live performance. We benefit for this aspect from the support of the Continuum French infrastructure network.

This work was supported by the IRISA research axis "Art, culture and heritage" grant CNRS and by French PIA grant ANR-21- ESRE-0030 (CONTINUUM).

Links:
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[L2] https://ars.electronica.art/center/de/deepspace/
[L3] https://www.irisa.fr/immersia/

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Fluid Simulation in Mixed Reality

by Muhannad Ismael, Roderick McCall and Joan Baixauli (Luxembourg Institute of Science and Technology)

Using mixed reality (MR) head-mounted displays (HMDs) for fluid simulations (FS) is challenging. This is due to the capacity in MR-HMDs to perform FS in real time with reasonable frames per second. FSMR (fluid simulation in mixed reality) models position-based fluids via an MR-HMD using remote particles system computing.

MR applications have recently gained traction owing to the rapid development of HMDs such as HoloLens version1/2 [L1], Apple Vision Pro and Meta Quest Pro. For instance, application areas include training, research studies in computer vision, remote collaboration and assistance, and entertainment. However, current MR-HMDs often lack the processing or graphical capacity, for example the frames per second rate is often quite low. A low frame rate can have adverse effects on simulations of complex models such as those including FS.

FS in MR can be an effective tool for training and education, especially in fields such as engineering, medicine, and chemistry. It permits the simulation of the behaviour of liquids, such as water, smoke, or other fluids, within a mix of real and virtual objects. These simulations consider the physics of fluid flow, viscosity, and interactions with both virtual and real-world objects.

For example, in engineering [1], FS in MR can be used to train engineers on fluid dynamics and fluid-structure interactions. By visualising the flow of fluids in real time, engineers can better understand the behaviour of fluids in various situations and make informed decisions on the design and optimisation. In medicine [2], FS in MR can be used to train medical professionals on the behaviour of blood flow in the human body. Medical professionals can better understand the flow of blood in real time and the effects of various medical interventions on blood flow. As a result, they can make informed decisions on patient care. FS is also important for the applications which provide laboratory safety training based on MR for those working in hazardous chemical laboratories without the risk of real-world hazards [L2]. It permits the simulation of hazardous situations, such as chemical spills or leaks, in a safe and controlled manner. This is important since it allows trainees to develop the necessary skills and knowledge to handle dangerous situations safely. However, where the realism of the simulation is too low, there is risk that some of the potential benefits of MR may be undermined.

However, FS is computationally expensive due to Navier-Stokes equations. These are a set of partial differential equations that describe the behaviour of fluids in motion, including liquids and gases. There are various techniques for FS using Navier-Stokes equations, including Finite Difference Method, Finite Volume Method, and Smoothed Particle Hydrodynamics. These techniques differ in the way they discretise the equations and simulate the fluid behaviour, but they all rely on solving the Navier-Stokes equations numerically.

Navier-Stokes equations can be computationally intensive, especially for complex scenes and high resolutions.

Achieving FS real-time performance is even harder considering the limited capacity of hardware resources of MR-HMD. In MR applications, real-time performance is essential to maintain a smooth and realistic experience for the user.

In the FSMR project, we employed Position Based Fluids (PBF) [3], which is defined as an algorithm using Smoothed Particle Hydrodynamics solvers but inheriting the stability of the geometric position-based dynamics algorithm. Hence, one advantage of PBF is that it is relatively fast and can be implemented efficiently on both CPUs and GPUs. This makes it a popular technique for real-time applications such as video games and interactive simulations. PBF is applied remotely on a local server and displayed on Microsoft HoloLens v2.

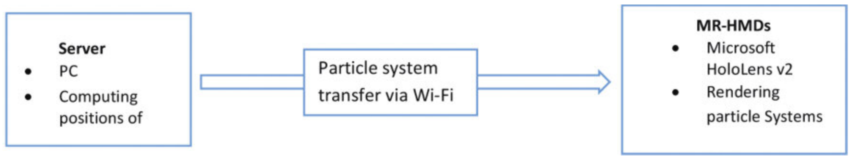

Figure 1: Schema general of the architecture of project.

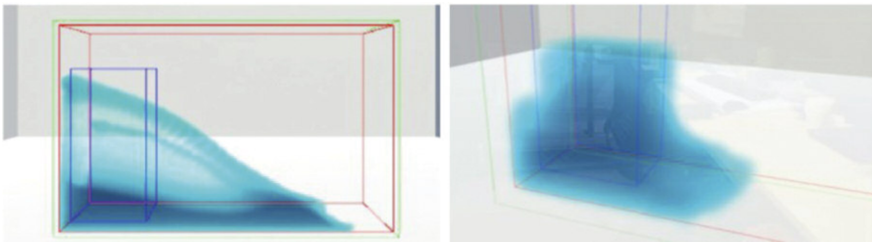

Figure 2: Position Based Fluids (PBF). Left: 60 FPS, implementation on desktop PC (number of particles 29K, RAM 32 GB, CPU–Intel Core I9 GPU– NVIDIA GeForce RTX 3080). Right: 8 FPS, Implementation on HoloLens v2 with same number of particles.

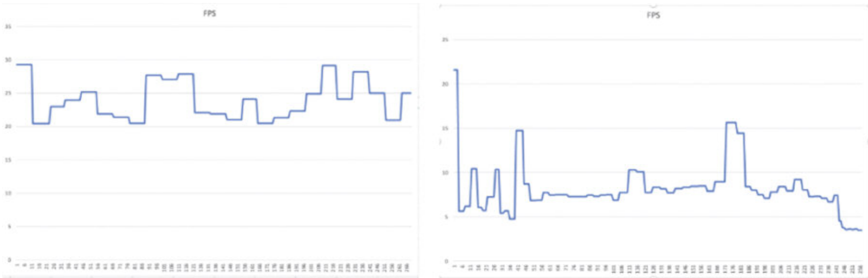

Figure 3: Left: Remote PBF computing with 24 fps in average. Rigth: Local PBF computing with 8 fps in average.

We have evaluated the performance of PBF using HoloLens v2 and desktop PC as illustrated in Figure 1. The average number of Frame Per Second (FPS) was 8 FPS and 60 FPS on HoloLens and PC respectively (see Figure 2). PBF which consisted of computing density, pressures and total force acting on each particle is applied on desktop PC used as local server. The particle system is then transferred via Wi-Fi connection to MR-HMDs where a rendering process is applied. Rendering a particle system remotely on a local server could affect the real-time performance due to the size of rendering volume that is transferred via Wi-Fi connection. Therefore, in this project, we decide to compute only the particle system on the local server and then transfer this to the MR-HMD as a set of 3D points. The points are then rendered on the MR-HMD. This technique resulted in 25fps. (see Figure 3).

The results are encouraging; however, higher fps could be achieved by optimisation of the date being transferred from the local server to the MR-HMD via Wi-Fi. Therefore, for future activities, we propose (1) streaming the particle system using TCP sockets which permits the establishment of a connection and the exchange of data reliably and in the correct order (2) to reduce network bandwidth requirements and achieve real-time data streaming. For (2) LZ4, Zstandard or Brotli compression methods could be applied to compress the particle system. Finally, (3) we plan to use a little-endian network format which is a way of storing binary data in which the least significant byte comes first. The latter will ensure that the compressed particle system data can be easily transmitted and received over a network.

In conclusion, we have presented an overview of an approach for fluid simulation within MR-HMDs and suggested future areas of work. Such an approach has the potential to be relevant in a large number of domains.

The project was funded internally by Luxembourg Institute of Science and Technology.

Links:
[L1] https://www.microsoft.com/fr-fr/hololens
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Virtual and Augmented Reality Monitoring and Planning System

by Maria di Summa (CNR-STIIMA), Nicola Mosca (CNR-STIIMA), and Angelo Cardellicchio (CNR-STIIMA)

The railway sector has always played a key role in communication systems and today, safety standards within this sector has reached very high levels. However, despite these high standards, the industry's goal remains achieving a completely accident-free status by leveraging resources and technologies.

In the current landscape, companies across various industries are showing keen interest in new technologies such as virtual reality (VR) and augmented reality (AR), which were once predominantly associated with the the gaming industry. The key to understanding this renewed interest lies in the integrated use of these technologies [1]. This trend towards the synergistic use of different technologies to optimise results is documented in the literature [2].

In response to the imperative to enhance safety levels in the railway sector, Mermec, an Italian company specialising in rail transport technologies and industrial applications, collaborated with the CNR-STIIMA institute and a small company from southern of Italy, Advantech srl, to introduce the VRail project - Virtual and Augmented Reality for Railways. The project aims to develop a complex monitoring system for railway infrastructure based on the most innovative and emerging technologies available on the market today.

The project involves the creation of an integrated monitoring system that enhances operator awareness and planning capabilities within the railway sector. The system comprises three components: data collection from the field, processing to identify anomalies, and immersive presentation through virtual and augmented reality scenarios.

Point clouds representing sections of railway infrastructure are acquired and transformed into interactive virtual environments, that can be navigated interactively by an operator responsible for planning maintenance interventions (Figure 1). Within this virtual environment, the operaters have at their disposal a series of additional information obtained thanks to the use of deep-learning algorithms, and an enjoying a realistic vision of the state of the places. This additional information increases the operators' awareness and makes it easier for them to plan maintenance operations.

Maintenance instructions prepared by planning operators within the virtual environment are presented in augmented reality to support maintenance workers in identifying intervention areas and executing tasks effecively.

The proposed system represents an interesting and innovative planning tool that allows multiple users to interact remotely, plan maintenance interventions, and carry them out using systems to support decisions and maintenance operations.

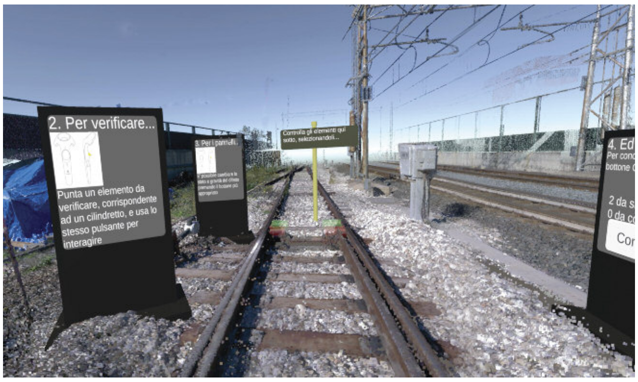

Figure 1: Stretch of railway infrastructure in virtual reality.

The VR environment was created by implementing field-acquired point clouds in Unity using a 3D laser scanner called the BLK360 [L1]. The virtual reality environment can be viewed using the HTC Vive Pro2 viewer [L2]. The deep-learning system analyses the state of the bolts that fix the sleepers to the tracks and categorises them as intact, damaged, or requiring inspection. The status identified by the intelligent system for each bolt is displayed in the virtual environment. Within the virtual environment, the operator in charge of planning interventions can accept or reject the suggestions of the intelligent system. Finally, the choices made by the design operator are transmitted to the augmented reality system, which will support the maintenance operators in carrying out their task.

Developing a complex system to support maintenance and planning activities is fundamental in the industrial and transport sectors. This method connects and verifies different tasks to improve security using mixed reality and artificial intelligence. Possible applications range from the industrial sector to the transport sector.

Future studies may explore similar systems in different scenarios and investigate alternative hardware devices to solve technical problems. It is fascinating to understand how to interact better in a virtual environment.

Links:

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Cooperative Situational Awareness in Traffic Environments Using AR Technologies

by Gerasimos Arvanitis (University of Patras, AviSense.ai), Aris S. Lalos (ISI, ATHENA R.C.), and Konstantinos Moustakas (University of Patras)

In recent years, Extended Reality (XR) technologies have transformed the interaction between humans and machines, especially in dynamic environments like automotive and transportation. By providing drivers with relevant Augmented Reality (AR) information about their surroundings, we can enhance drivers' capabilities and potentially improve their behaviour, safety, and decision-making in critical situations within rapidly changing environments. Connected Autonomous Vehicles (CAVs) offer the advantage of intercommunication, creating a network of connected vehicles known as cooperative situational awareness. This connectivity presents numerous opportunities, including the sharing of AR information related to the observed objects-of-interest between vehicles within the system (simultaneous and/or asynchronous). Such information transmission allows one vehicle to relay valuable observations to another, enhancing overall system awareness and efficiency.

The proposed solution aims to provide intuitive and subtle AR information to improve the driver's situational awareness and promote a sense of safety, trust, and acceptance. Cooperative information from connected vehicles, facilitated through Vehicle-to-Everything (V2X) infrastructures, will be leveraged to enhance the accuracy of the results. The key components of the methodology are illustrated in the schematic diagram (Figure 1). In this study, we consider two distinct use cases: i) the presence of CAVs with spatiotemporal 4D connectivity, where multiple vehicles share the same map of a town and move simultaneously (Figure 2); and ii) vehicles with only spatial 3D connectivity, where multiple vehicles are in spatial proximity (on the same map) but not necessarily temporal proximity (at different times) (Figure 3).

To ensure the driver is efficiently informed about potentially dangerous situations while driving, we have developed an AR rendering notification system, alerting drivers for potentially hazarous objects-of-interest along the road, such as potholes and bumps (static objects) or moving vehicles and Vulnerable Road Users VRU (dynamic objects), facilitated through a centralised server. The transmitted information includes the Global Positioning System (GPS) location, geometrical characteristics, timestamp, and semantic label of the detected objects. The system then sends the relative AR information to nearby vehicles, providing early warning from a significant distance. This helps overcome the limitation of sensors in identifying potentially dangerous objects from long ranges. For drivers, the AR interface of the vehicle displays the loca-

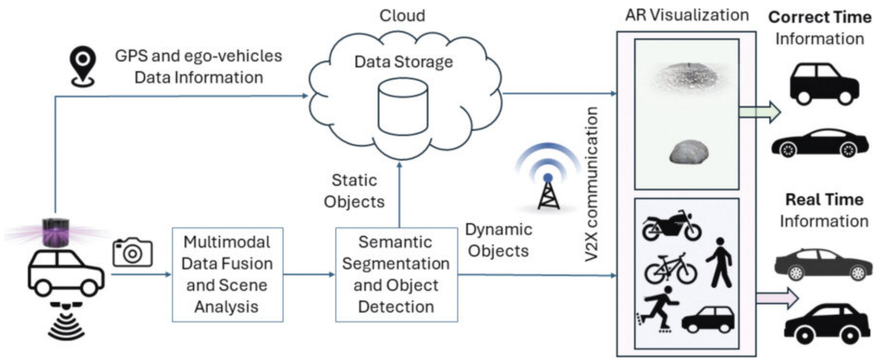

Figure 1: Methodology of the proposed method.

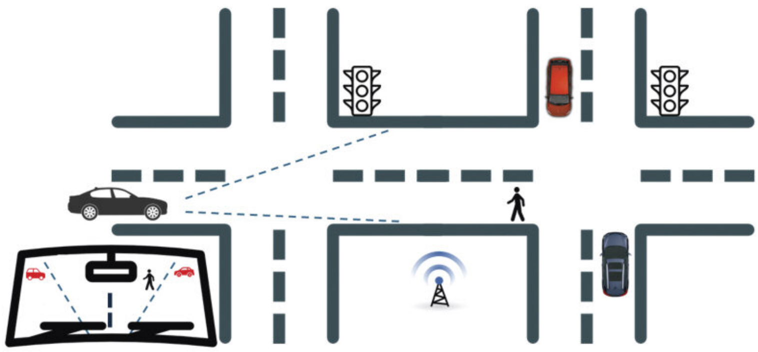

Figure 2: Cooperative situational awareness in the simultaneously communication use case.

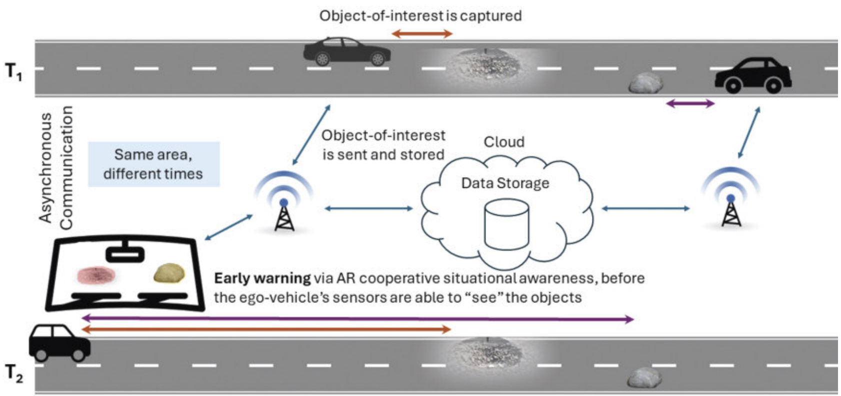

Figure 3: Cooperative situational awareness in the asynchronous communication use case.

tion and nature of the potentially upcoming dangerous object in a non-distracting manner. Through this communication system, drivers can receive early visual warning about potential hazards that may not yet be within their field of view or are obstructed by other objects, thereby enhancing their performance and decision-making abilities.

The detected objects-of-interest are displayed on the AR interface within the driver's field of view, which may be a head-up display (HUD) or a windshield display. AR object visualisation is achieved through projection. Assuming the positions of both the AR interface and the system of cameras/LiDARs relative to the world are known, a transformation matrix is constructed to map the points of the LiDAR's point cloud from its coordinate system to the AR interface's coordinate system. This transformation between the two coordinate systems typically involves a series of operations: scaling, rotation, and translation. However, since both coordinate systems are orthonormal, scaling can be omitted. Furthermore, given that the LiDAR and AR interface are both fixed on the vehicle and aligned with each other, the rotation matrix can also be omitted, as there is no loss of generality in assuming that the two coordinate systems are already aligned. Based on these assumptions, the transformation of LiDAR coordinates into the AR interface's coordinates involves a straightforward translation. To project the points of the point cloud onto the AR interface, we adopt a simple pinhole camera model [1]. For instance, if the AR interface is an AR windshield, then the windshield serves as the image plane, and the driver's head serves as the principal point with coordinates (x0, y0). Therefore, the focal distance f = (fx, fy) represents the distance from the driver to the image plane. With the dimensions of the image plane (windshield), including the aspect ratio, known, the frustum is fully defined, enabling the projection from a point in 3D windshield coordinates (x, y, z) to pixels (u, v) on the image plane.

To enhance road safety, the automotive industry initially aimed to create fully autonomous vehicles. However, the technology is not yet mature enough to completely replace the driver. Additionally, unresolved issues concerning legal and societal matters, as well as the trust and acceptance of end-users, hinder the achievement of full-scale autonomy in the near future [2]. In response to this challenge, we assess methods that facilitate a safe, seamless, progressive, and dependable cooperative situational awareness, fostering feelings of trust and acceptance. In future work, explainable AI technologies will be employed to enhance the effectiveness and timeliness of informing drivers about potential hazards or other pertinent AR information. This optimisation of visual content will focus on factors such as explainability, trustworthiness, and ease of understanding. The collected information will be categorised and prioritised to ensure that drivers are not overwhelmed or distracted by irrelevant data. Additionally, efforts will be made to present information in a non-intrusive manner, striking a balance between enhancing situational awareness and avoiding information overload that could distract the driver.

This work is implemented in the framework of the prestigious basic research flagship project PANOPTIS (H.F.R.I. Project Number: 16469), aiming to develop AI-based AR tools to strengthen users' abilities and improve cooperative situational awareness, to avoid critical cases of situational disabilities, reduced perceptual capacity due to physical limitations of human sensors, mental and physical fatigue.

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Immersive Virtual Colonoscopy

by Anderson Maciel (Técnico Lisboa), Catarina Moreira (University of Technology Sydney), and Joaquim Jorge (Técnico Lisboa)

Desktop-based virtual colonoscopy has been proven to be an asset in identifying colon anomalies. The process is accurate, although time consuming. In this article, we present a new design exploring elements of the VR paradigm to make the immersive analysis more efficient while still effective.

Colorectal cancer (CRC) is the third-leading cause of cancer-related mortality both in the United States and worldwide. In 2023 alone, it is projected that around 153,020 individuals will receive a CRC diagnosis, and approximately 52,550 individuals will sadly lose their lives to this disease [1]. Thus, prevention and treatment of colorectal cancer require the early detection of adenomas, polyps, and CRC. While traditional colonoscopy (TC) is the gold standard. However, it is invasive and requires uncomfortable preparation since it requires a scope to be inserted through the rectum.

Virtual Colonoscopy (VC) was created to solve some TC disadvantages [2]. Through CT scans and desktop programs, radiologists navigate through a reconstructed colon in a two-way path: from the rectum to the cecum and from the cecum to the rectum to avoid missing anomalies in folds. Despite solving invasiveness, it brings its disadvantages. Navigation is restricted to a single view, causing uncertainty regarding the types of polyps, leading to a higher referral rate to colonoscopy and superior cost. While VC can detect most colon anomalies, it is highly time-consuming, taking much longer than a conventional total colonoscopy. Moreover, the exam only considers the inside of the colon; extracolonic lesions may still exist. Thus, the need for further exams increases the cost, and on top of that, false positives can occur.

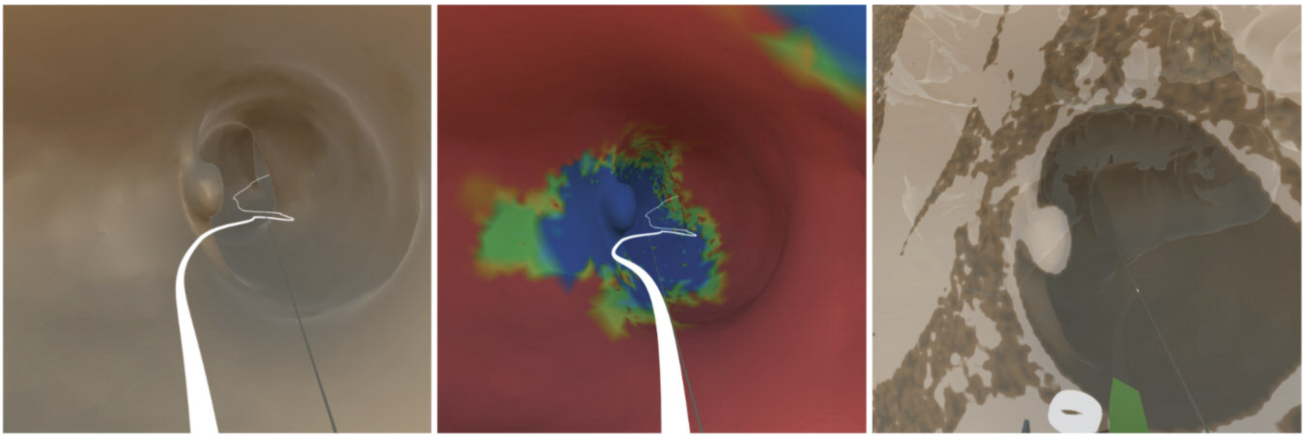

Figure 1. Highlights of the immersive colonoscopy viewer. In (a), a view from inside the colon in VR shows a medial axis line in white. (b) colourmap view of eye-tracked data, indicating the areas already examined in blue and not yet seen in red. (c) CT data plane visible in situ, where the tissue density can be inspected to help detect disease.

VC proved effective and started to be used in clinical practice. Researchers focused on finding new means to explore and analyse the available data, proposing Immersive Virtual Colonoscopy(IVC) [3]. In IVC, a 3D model of the colon is reconstructed from CT scans and viewed through VR. IVC has unique advantages when compared to desktop VC. It allows radiologists to freely explore the inside and outside of the colon using natural head and body motion to better analyse volumetric data with stereopsis and parallax cues. Indeed, 3D visualisation positively influences search tasks. Navigation is more flexible since radiologists are not bound to a single path, and measures can be taken directly in 3D. A major challenge remains in designing an efficient VR interface for IVC. Our work focuses on reducing exam duration while increasing precision and recall.

Our Immersive Virtual Colonoscopy Design

Our IVC design supports the same tasks as VC but with VR elements and metaphors. The system was developed on Unity, as it offers a favourable environment to integrate the colonoscopy procedure simulation with the VR equipment. The radiologist starts with a view from outside of the colon. They can rotate the colon for external inspection, point to the colon to teleport to the pointed position, or simply switch to the inside view. Once inside, they can move using the "fly-through over the centre line" mechanism, which allows doctors to navigate seamlessly through the colon by following its central path using the controllers. In addition to navigation, the interface incorporates measurement capabilities directly in 3D. Users can utilise measurement tools to assess various aspects of the colon, such as the diameter of polyps or the length of potential abnormalities. These measurements are recorded and stored, enabling radiologists to review and compare previous measurements during subsequent sessions. This feature proves particularly valuable for monitoring the progression of conditions or tracking changes over time.

Another noteworthy feature of virtual colonoscopy is the inclusion of a coverage visualisation using a heatmap, shown in Figure 1b, which depicts via a colour gradient (red for the not-seen areas and blue for the most-seen areas) to highlight areas of the colon that have yet to be thoroughly examined or remain unseen during the procedure. This feature assists users in identifying potentially overlooked regions, prompting them to redirect their attention to those areas and ensuring comprehensive coverage during the virtual colonoscopy examination.

Final Remarks

We designed a viable VR interface for the VC diagnostic procedure. We explored further some of the elements previously addressed in the literature, such as the navigation and measurement tools. Yet, we innovated with eye tracking to estimate the coverage and with an in situ CT slice viewer. Our preliminary findings suggest that these technologies enhance IVC's effectiveness by providing valuable insights into the user's decision-making process and improving the accuracy of lesion detection and diagnosis. This prompts new research to measure the impact of our techniques.

This work was partially supported by FCT - Portuguese National Science & Technology Foundation grant 2022.09212.PTDC (Xavier) under the auspices of the UNESCO Chair on AI & VR.

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ADV.E.N.T.U.R.E
ADVancEd iNtegraTed evalUation of Railway systEms

Advanced Integrated Evaluation of Railway Systems

by Davide Basile, Maurice ter Beek, Felicita Di Giandomenico (CNR-ISTI), Laura Carnevali and Alessandro Fantechi (University of Florence)

Researchers from the Software Technologies Lab (STLAB) of the University of Florence and the two research labs Formal Methods and Tools (FMT) and Software Engineering and Dependable Computing (SEDC) of CNR-ISTI join forces to work on innovative solutions for the evaluation of railway systems. The research is conducted in the context of the national project ADVENTURE funded by the Italian Ministry for Universities and Research (MUR) under the program for Projects of National Interest (PRIN).

The Railway domain is expected to contribute significantly to the European Green Deal by improved digitalisation and data analytics. Challenges include the goal to “increase the levels of safety, security, reliability, and comfort, thereby maintaining the EU’s leadership in transport equipment manufacturing and services” [L1]. To this end, railway systems need to guarantee a set of expected Key Performance Indicators (KPIs) such as safety of the train movement, capacity (e.g. number of trains or passengers per time unit), energy efficiency, operating cost, etc. These KPIs are determined by the operation of innovative subsystems that cooperate towards the smooth performance of railway systems, supporting monitoring, command, and control of physical railway equipment.

The specific and complex interactions among these subsystems raise challenges that put at risk the accurate and efficient evaluation of the KPIs, as well as safe interoperability. First, to address them, it is necessary to overcome some current limitations of state-of-the-art hierarchical and compositional techniques for the estimation of non-functional attributes of component-based systems, in order to properly fit the railway needs. Second, advancements in formal specification of behavioural interfaces among heterogeneous components are required in order to improve the reliability of the composition of railway subsystems while reducing their cost.

The project ADVENTURE (ADVancEd iNtegraTed evalUation of Railway systEms) [L2] targets these challenges by developing innovative solutions for the evaluation of railway systems. The project focuses on the following three objectives, using Model-Driven Engineering (MDE) methods and multi-paradigm or multi-formalism approaches to help create bridges between different levels of abstraction:
- Qualitative evaluation of the safety of complex distributed railway systems, by means of diverse techniques like compositional model checking, synthesis of specifications provided as behavioural interfaces and tool support for relating specifications with implementations.

- Quantitative evaluation of dependability attributes despite of failures, in particular related to communication failures, by means of quantitative modelling and analysis of the timed failure logic of the system under analysis.
- Quantitative evaluation of trade-offs between availability/performance and energy efficiency, taking into account different smart policies of energy saving as well as failures, criticalities and priorities of the system under analysis.

The solutions developed during the project will be validated by their application to systems that are highly representative of the innovation trends in railways, namely decentralised interlocking, standard interfaces and smart de-icing systems.

A variety of formal methods and tools have successfully been applied to railway systems to address challenges in the railway domain, involving both qualitative and quantitative techniques [R1,R2,R3]. ADVENTURE aims to advance the state-of-the-art in the formal specification of railway interfaces as behavioural contracts, their formal verification and connection with implementations realised using a correct-by-design methodology. ADVENTURE also aims to advance the state-of-the-art in failure logic analysis of component-based systems. First, by the definition of an agile MDE approach tailored to the specific needs of the railway domain, concerning both the system structure and the mechanisms of failure propagation. Second, by the definition and integration of compositional analysis methods capable of handling the complexity of the railway systems being considered, in particular in terms of the number of components and failure modes. Finally, ADVENTURE aims to advance the modelling and analysis of smart deicing systems by introducing more comprehensive aspects, such as traffic load on individual railway switches.

ADVENTURE, funded by the European Union – NextGeneration EU, will run until November 2025 and is coordinated by Alessandro Fantechi from the University of Florence, who is moreover an expert member of the Scientific Steering Group of the Europe's Rail Joint Undertaking [L3].

Links:
[L1] https://kwz.me/hAQ
[L2] https://stlab.dinfo.unifi.it/pages/projects/adventure/
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Distributed Information Security Auditing Using Blockchains

by Lukas König, Martin Pirker, Simon Tjoa, Peter Kieseberg (St. Pölten University of Applied Sciences)

Information security is becoming increasingly important due to the growing threats in the digital space. In supply chains in particular, it is essential to ensure that all participating companies have achieved an adequate level of protection, as vulnerabilities in one organisation can jeopardise the entire supply chain. We present a concept for blockchain-based, distributed information security audits, where companies can prove their level of protection to each other and increase trust in supply chain security.

Information security audits, especially in the context of globally established standards such as ISO 27001, fulfil the purpose of an independent and objective assessment of a company's security level and serve as an important part of realising security strategies, especially when considering ICT-critical infrastructures. Still, the current approaches mainly focus on single organisations. As securing supply chains is increasingly becoming a central aspect of modern companies' overall risk assessment, the security and resilience of the underlying ICT systems of partners, suppliers as well as vendors, are playing an increasingly important role. This has also been recognised by the EU, which has addressed this issue at legislative level with the Cyber Resilience Act, as well as the NIS2 directive.

When it comes to the relationship between safe supply chains and the level of security that an individual organisation possesses, it is possible for vulnerabilities at a single point to put the entire supply chain in jeopardy over the course of time [1]. Consequently, it is not only essential for each single organisation to conduct routine security checks, but it is also essential for all of the organisations that are a part of a supply chain to participate in such checks.

Although securing supply chains is becoming increasingly important, there is still a lack of scientific work on this topic. Previous publications on distributed auditing deal with, for example, metrics for security maturity levels, records of network monitoring, or decentralised risk management. However, an actual decentralised system for securing and communicating information security audits has not yet been described, yet communicating actual threats, vulnerabilities and (successful and unsuccessful) attacks along a supply chain is key for enhancing its resilience.

One major concern is that any exchange of this kind of audit information might reveal sensitive information about an organisation's security gaps, which means that sharing these results is not in the organisation's own interest in terms of protection. Sharing information about security incidents, technical and organisational measures with external third parties requires a high level of trust, as such information can reveal ob-

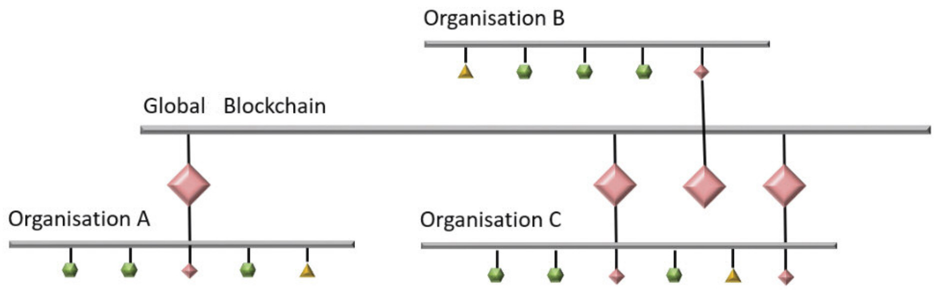

Figure 1: A global blockchain for validating audits across organisations [3].

vious weaknesses in an organisation and therefore pose a threat to general information security.

Our basic approach to a distributed audit system [2] thus includes external and internal information security audits, i.e. audits conducted by each organisation itself, as well as audits conducted by external, independent auditors. Security audits can reveal a lot of sensitive information about an organisation. Regardless of whether the outcome of an audit is positive or negative, an audit implicitly reveals important information about company strategies and business processes. For this reason, an approval model ensures separation between organisations. This guarantees that sensitive information can only be viewed by authorised parties. In other words, internally within the company, externally, and a special position for independent inspection bodies. It is therefore a system in which trust between companies is ensured by trust in the technology.

Technologically, in our distributed audit system each participating organisation operates a local/internal version of a blockchain on which the results of information security checks are stored. These local and organisation-internal checks can be carried out both as an internal audit and as an external audit by an independent audit body. Each organisation can carry out any number of checks on the internal blockchain and store the results in a tamper-proof and interlinked manner.

A global blockchain is used to prove the security level of an organisation to other organisations, for example as part of a supply chain (see Figure 1). It is operated by an independent organisation and filled with data blocks and information. Entries for the global blockchain result from validation checks by the independent body of each participating organisation. This involves checking the organisation and its previous local blockchain entries and then attaching a validation block to the local and global blockchain.

In future work we plan on extending this approach to the realm of threat-information sharing, as for many highly integrated supply chains the topic of providing partners with relevant security information can even be more important than securing less important system parts in their own company. Still, as such chains might be very flexible and a multitude of partners might participate, a blockchain-based structure has a lot of benefits over a centrally provided server-based information-exchange approach. This form of a decentralised ISMS would also need functions for information override and correction, yet providing a full history of all shared security information would lead to enabling security managers to prove their information status at the time of decision-making.

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Designing for Wall-Sized Displays: Challenges from the Field

by Lou Schwartz, Valérie Maquil and Mohammad Ghoniem (Luxembourg Institute of Science and Technology)

Wall-sized displays (WSDs) are large interactive displays with specificities to consider when designing applications for them, but there is no standard or guidelines to support designers. Therefore, we organised a focus group with nine researchers to identify the main challenges encountered during the design of collaborative problem-solving applications for WSDs.

WSDs are large interactive displays increasingly used in various fields in the public space (to display contextual information, entertainment or artistic purposes) but also to support design and collaborative decision-making (i.e. in the fields of automotive design, architecture, traffic management, surgical flow management, ICU data and product design). Such displays “create a coherent physical view space that is at least of the size of the human body and exhibits a significantly higher resolution than a conventional display.”[1]. Their configurations vary in terms of size, orientation, visualisation technology, display setup, means of interaction, fields of application and location [2]. But such diversity complicates the design of applications for WSDs. Therefore, to better understand the challenges of designing for WSDs and to complete previous work [1,3], we organised a focus group with nine researchers. These researchers mainly worked on the design of applications and interactions for WSDs.

The participants had different expertise levels in the design of such applications for WSDs, from beginner to experienced. The purpose of their designed applications included collaborative decision-making support systems, complex data visualisation, popularising science for young people in a science museum, studying the decision to cross the road in front of autonomous vehicles, and visualisation of data from a building model from several views. They covered different targeted areas: 4D in architecture, logistics in times of crisis, engineering, energy communities, autonomous vehicles, and scientific dissemination. From the discussions, nine categories of challenges emerged.

"More interactions" refers to the challenges arising from the combination of several interaction methods (i.e. gestural, touch, tablets, sensors, etc.). It deals with minimising the use of equipment while ensuring the robustness of the system to modify data, texts, and models directly on the WSD, to manage role-specific interactions and to identify the author of the action.

"More users" refers to challenges concerning the management of occlusions, the competition between users, and new collaborative interactions for a task (i.e. drag and drop carried out collaboratively by people located at either end of the WSD). It further concerns managing large groups (more than ten people) including dealing with social dynamics and different roles, bringing together different people with different areas or levels of expertise with different information and format needs, managing personal spaces and information sharing in the common space.

"More space around" refers to the size of the room in proportion to the size of the WSD and of the targeted group. It deals with the management of the physical fatigue induced by moving along the screen, and by moving back and forth to get an overview or interact. It also includes managing the physical space by providing furniture if necessary, adjusting light conditions, and ensuring that all information is legible from everywhere.

"Different durations of use" are observed depending on the purpose of the WSD. Public WSDs are used during short interaction sessions, and grabbing the attention of passers-by is important. But problem-solving sessions can last a long time (between 30 minutes and 4 hours), and in this case, it is important to manage interruptions, and sequential work by several groups, by saving and reloading a session, for instance.

"More complex content" is related to defining the needed information and how it should be displayed to provide the right level of information for all the people present. Displays need to be adapted to their work habits, with content being organised into zones, depending on their impact (main, secondary and detail information). Important content should be emphasised, and, in the case of representations of the same content,

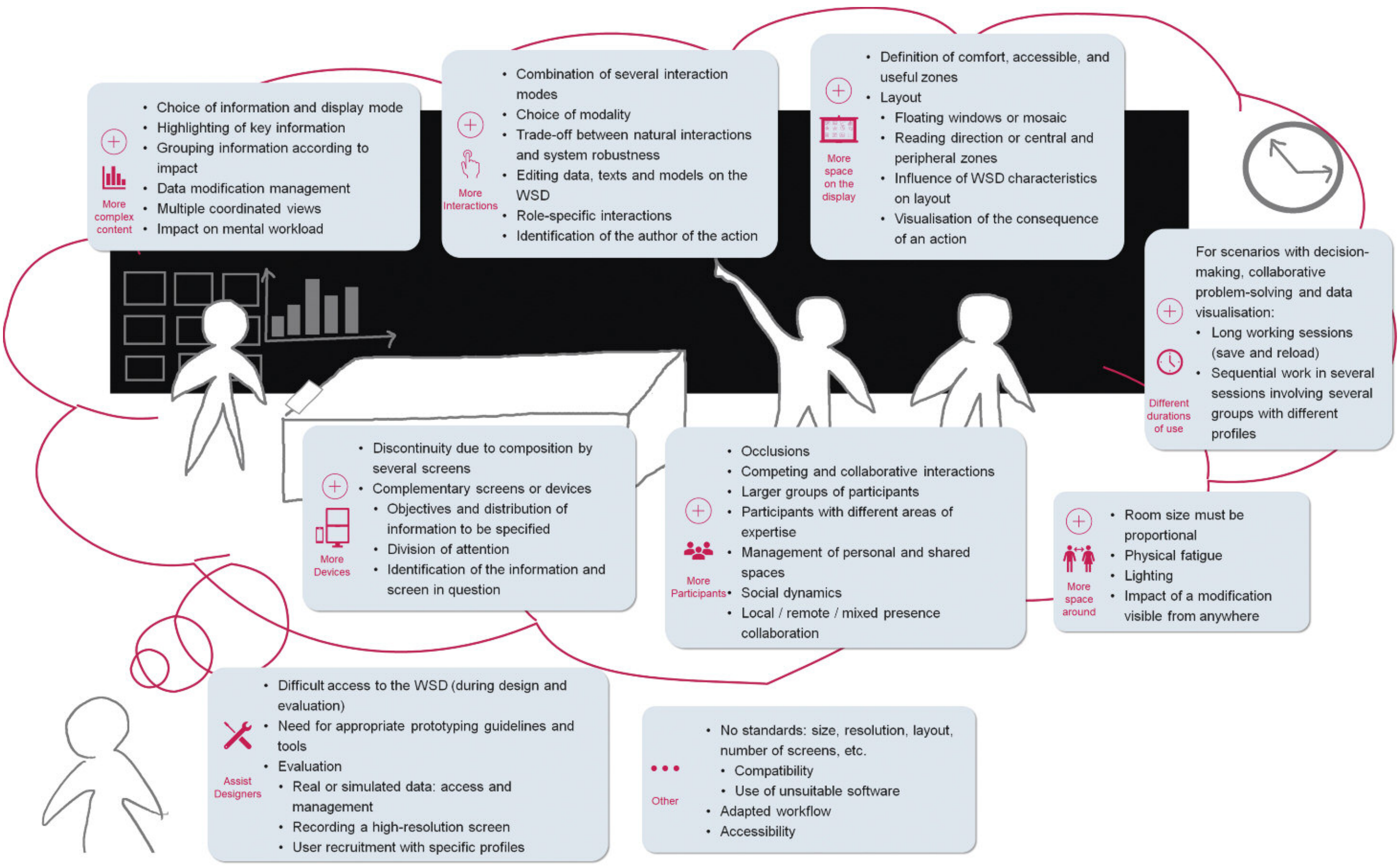

Figure 1: Nine challenges encountered in the field when designing for wall-sized displays (WSDs), resulting from a focus group with nine researchers working on the design of applications and interactions for WSDs for collaborative decision support and collaborative visualisation of complex data on two devices: a concave wall and a vertical wall, which can be complemented by a touch table, a tangible table or other displays.

modifications need to be shown everywhere. Finally, this challenge also concerns the management of the users' mental workload.

"More devices" is related to the several screens that a WSD can be composed of, but also to all the other devices that can be used to complete the WSD setup (i.e. supplementary display, interactive tabletop, personal devices, sensors, etc.). This raises concerns about the synchronisation of all the devices and their integration in the users' workflow.

"More space on the display" refers to the management of the size of the WSD (too high or too low will leave certain areas inaccessible), and how the main information can be placed while defining comfortable, accessible and useful zones on the display. This challenge concerns also the layout management and the on-the-fly layout adaptations.

"Assist designers" regroups the lack of guidelines, prototyping tools, and best practices in design and testing. Accessing real data during the design process, recruiting users with the right expert profile and access to the equipment, can be complicated (not available, not already built or too far away).

"Other" challenges concern the compatibility (no standard in terms of WSD characteristics, the most appropriate configuration for each situation and difficulty to use existing software on a WSD). But also, the management of the workflow for complex tasks, and the accessibility for specific audiences (i.e. children, elderly people or people with disabilities).

To conclude, it is difficult to make the right choice when designing applications for WSDs. There is a lack of tools and methods adapted to WSDs, that take into account their the nine challenges explained above. More research is needed to better explore these challenges but also to propose solutions to address them.

References:

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[2] C. Ardito et al., "Interaction with large displays: A survey," ACM Comput. Surv., vol. 47, no. 3, Article 46, Feb. 2015. https://doi.org/10.1145/2682623.

[3] L. Lischke et al., "Challenges in designing interfaces for large displays : The practitioners' point of view," in Proc. of NordiCHI '20, ACM, 2020. https://doi.org/10.1145/3419249.3421240.

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Call for papers

Edge AI Meets Swarm Intelligence

18 September 2024, Dubrovnik, Croatia

Edge AI represents a novel computing paradigm designed to facilitate local data storage and processing, with AI algorithms enabling data treatment directly at the edge of the network. This approach aims to bring intelligence to the end-devices, facilitating real-time decision-making and empowering devices to operate autonomously, reducing reliance on external cloud services. Two Horizon Europe projects - SmartEdge and AIoTwin - are jointly organizing the "Edge AI meets Swarm Intelligence" workshop to disseminate on-going research outcomes not only of these two projects, but also of related projects.

One of the key topics of interest is to develop low-code programming tool chains or platforms for edge intelligence to enable swarm computing paradigms. The tools will reduce the efforts of building smart systems requiring a collective of heterogeneous devices, sensors, vehicles and robots to collaborate towards a common goal.

The primary goal of this workshop is to foster collaboration and the exchange of ideas among researchers and stakeholders. The workshop can provide a platform for participants to share their experiences, best practices, case studies, and to identify emerging research areas and potential solutions to existing challenges.

Topics of Interest

We invite submissions related to the design, development, and evaluation of architectures, technologies, and applications for "Edge AI" and "Swarm Intelligence", including but not limited to:

- Network optimization and interoperable protocols for Edge AI and Swarm Intelligence
- Novel system architectures and hardware designs in Edge AI and Swarm Intelligence
- Network security, data privacy, confidence, and trust in Edge AI and Swarm Intelligence
- AI-enabled resource allocation, federated learning, and swarm intelligence
- Next generation smart use-cases enabled by Edge AI and Swarm Intelligence
- Intelligence in distributed computing continuum systems
- Novel results in embedded AI, in-network computing or heterogeneous computing
- Methods, resources, and experimental findings in autonomous systems.

Important dates

- Open for Submission: 1st, May
- Abstract Submission: 15th, June
- Full Submission: 22th, June
- Notifications: 2nd, August
- Camera-ready: 23rd, August

More information:

https://www.smart-edge.eu/summer-school-2024/

SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

Call for Proposals

Dagstuhl Seminars and Perspectives Workshops

Schloss Dagstuhl – Leibniz-Zentrum für Informatik is accepting proposals for scientific seminars/workshops in all areas of computer science, in particular also in connection with other fields.

If accepted, the event will be hosted in the seclusion of Dagstuhl's well known, own, dedicated facilities in Wadern on the western fringe of Germany. Moreover, the Dagstuhl office will assume most of the organisational/ administrative work, and the Dagstuhl scientific staff will support the organizers in preparing, running, and documenting the event. Thanks to subsidies the costs are very low for participants.

Dagstuhl events are typically proposed by a group of three to four outstanding researchers of different affiliations. This organizer team should represent a range of research communities and reflect Dagstuhl's international orientation. More information, in particular details about event form and setup, as well as the proposal form and the proposing process, can be found on

https://www.dagstuhl.de/dsproposal

Schloss Dagstuhl – Leibniz-Zentrum für Informatik is funded by the German federal and state government. It pursues a mission of furthering world class research in computer science by facilitating communication and interaction between researchers.

Important Dates

- *Next submission period:* October 15 to November 1, 2024
- *Seminar dates:* Between September 2025 and August 2026 (tentative).

43rd SAFECOMP Conference and 19th DECSoS Workshop

Florence, Italy, 17 September 2024

The renowned international SAFECOMP Conference takes part this year in Florence, Italy, from 17-20September, the first day being reserved for several parallel workshops (Workshop Day). The key theme is Safety in a cyber-physical interconnected world.

Established in 1979 by the European Workshop on Industrial Computer Systems, Technical Committee 7 on Reliability, Safety and Security (EWICS TC7), SAFECOMP has contributed to the progress of the state-of-the-art in dependable application of computers in safety-related and safety-critical systems. SAFECOMP is an annual event covering the state-of-the-art, experience and new trends in the areas of safety, security and reliability of critical computer applications.

Of particular interest for the ERCIM community may be the co-located 19th DECSoS workshop, co-organized since many years by the ERCIM DES (Dependable Embedded SW-intensive Systems) Working Group (Erwin Schoitsch, Amund Skavhaug). Papers may still be submitted, the deadline for workshop papers will be 15th of May 2024 (extended deadline), for late papers please address the Chairperson erwin.schoitsch@ait.ac.at . The workshops undergo an evaluation process, with details available on the SAFECOMP website. All papers for the workshops are peer reviewed by at least three independent reviewers and published by Springer, LNCS series, as SAFECOMP Workshop Proceedings, separate from the Proceedings of the main conference.

Links:
https://www.safecomp2024.unifi.it/
https://www.safecomp2024.unifi.it/vp-16-workshops-at-safecomp.html

ERCIM
European Research Consortium for Informatics and Mathematics

Horizon Europe Project Management

A European project can be a richly rewarding tool for pushing your research or innovation activities to the state-of-the-art and beyond. Through ERCIM, our member institutes have participated in more than 100 projects funded by the European Commission in the ICT domain, by carrying out joint research activities while the ERCIM Office successfully manages the complexity of the project administration, finances and outreach.

Horizon Europe:How can you get involved?

The ERCIM Office has recognized expertise in a full range of services, including:

- Identification of funding opportunities
- Recruitment of project partners (within ERCIM and through ournetworks)
- Proposal writing and project negotiation
- Contractual and consortium management
- Communications and systems support
- Organization of attractive events, from team meetings to large-scale workshops and conferences
- Support for the dissemination of results.

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Peter Grünwald Receives ERC Advanced Grant for Statistical Theory

Peter Grünwald, senior researcher in the Machine Learning group at CWI and part-time professor of Statistical Learning at Leiden University, has been awarded an ERC Advanced Grant. The grant, totaling 2.5 million euros, supports his research into developing a new theory of statistics.

Peter Grünwald. Photo source: CWI.

Grünwald's work introduces the concept of the e-value, which often proves more effective than the p-value in determining the significance of scientific results. This breakthrough addresses the flaws in the current methodologies which rely on p-values and confidence intervals, established in the 1930s and inadequate for scientific processes.

Traditional statistical methods, including p-values and confidence intervals, often lead to a incidence of false positives, contributing to what is known as the 'replication crisis' in science. These methods lack the flexibility required for research practices, where data are frequently added and analyses recalculated, particularly in experiments. The e-value, according to Grünwald, calculates the strength of evidence against a hypothesis, ranging from zero to infinity. A e-value indicates evidence that results are significant. This new approach allows for the addition of data at any point and the recalibration of the e-value without losing its interpretative power. Unlike methods, e-value-based confidence intervals remain valid no matter when or how often they are reviewed.

Grünwald's research proposal aims to replace traditional methods with these e-value-based techniques. This development promises to revolutionize statistical practices, making them adaptable to various scientific needs and reducing reliance on large data sets.

Grünwald expressed his gratitude for the EU's support of his approach, emphasizing that the new methods will enhance the safety and flexibility of statistical analyses, leading to more conclusions with less data.

More information:
https://kwz.me/hDT

VCAST Set to Launch in 2024

In an era where secure and transparent voting is crucial, VCAST emerges as a platform for online voting, ready for its official launch in January 2024. Developed by Stéphane Glondu, a research engineer at Inria, and Michael Houalef, a marketing and digital manager, VCAST is designed to enhance the security and transparency of voting processes across various sectors.

The platform operates on the principle of e-voting, with a strong emphasis on verifiability, compliance, assistance, security, and transparencys. This system facilitates the integration of voter lists and result sharing and ensures that every participant's vote is counted accurately and confidentially.

The genesis of VCAST is based on a program called Belenios, which Glondu and his team launched at Inria in collaboration with Loria. Belenios has proven its efficacy by managing over 5,000 online votes, involving more than 500,000 voters, demonstrating the robustness and reliability of the technology.

VCAST is tailored for use by sports clubs, trade unions, businesses, and homeowners' associations, reflecting its versatility and broad market appeal. The platform's design ensures that it remains user-friendly for both organizers and voters, simplifying the election process while maintaining rigorous security standards. This ease of use is backed by a security system developed through the Belenios program, known for its robustness over the years. Also, the VCAST platform was evaluated from an organisational perspective based on recommendations from the CNIL (the French data protection authority) and from an organisational perspective by a laboratory assigned by the ANSSI (France's national cybersecurity agency)

As VCAST prepares for its launch, it stands out for its technological innovation and commitment to open-source principles, offering transparency and security in digital voting.

Michaël Houalef (left) and Stéphane Glondu (right). Photo source: Inria

More information:
https://www.inria.fr/en/vcast-vote-security-confidentiality
https://www.inriastartupstudio.fr/en/home/

ERCIM – European Research Consortium for Informatics and Mathematics

ERCIM – the European Research Consortium for Informatics and Mathematics is an organisation dedicated to the advancement of European research and development in information technology and applied mathematics. Its member institutions aim to foster collaborative work within the European research community and to increase co-operation with European industry.

ERCIM is the European Partner of the World Wide Web Consortium.

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